CHAPTER 15

EARTHWORK OPERATIONS

A solid foundation must be prepared to support roads, runways, buildings, and other temporary or permanent structures. To accomplish this task, the Naval Construction Force (NCF) must perform earthwork operations, often referred to as **horizontal construction.**

Earthwork operations include much more than just moving the earth. As an EO, you must be able to use the techniques required to achieve the finished product. You accomplish this by planning and developing the steps to complete the project, studying and understanding project drawings, computing earthwork volumes, reading and using construction grade stakes, transferring elevations with leveling equipment, and understanding the characteristics of soils and the procedures used in earthwork operations.

PROJECT PLANNING

In the NCF, the entire history of each construction project, from the initial planning phase, through the execution phase, to the closeout phase, is documented in a standard nine-folder project package (fig. 15-1). This format is used on all tasked projects.

NCF PROJECT PACKAGE

FILE #1 GENERAL INFORMATION FILE

LEFT	Project Scope Sheet Tasking Letter Project Planning Checklist Project Package Sign-off Sheet
RIGHT	Project Organization Deployment Calendar Preconstruction Conference Notes Predeployment Visit Summary

FILE #2 CORRESPONDENCE FILE

LEFT	Outgoing Messages and Correspondence
RIGHT	Incoming Messages and Correspondence

FILE #3 ACTIVITY FILE

LEFT	Construction Activity Summary Sheets of Completed Activities
RIGHT	Master Activity Sheets Level 11 Level II Precedence Diagram Master Activity Summary Sheets Construction Activity Summary Sheets (Recommend including filled out 1250s and mineral products request)

Figure 15-1.—NCF project package outline.

FILE #4 NETWORK FILE

LEFT
- Computer Printouts
- Level III
- Level III Precedence Diagram

RIGHT
- Resource Leveled Plan for Manpower and Equipment
- Equipment Requirement Summary

FILE #5 MATERIAL FILE

LEFT
- List of Long Lead Items
- 45 Day Material List
- Material Transfer Request
- Add On/Reorder Justification Forms
- Bill of Materials/Matetial Takeoff Comparison Work Sheets
- Material Takeoff Work Sheets

RIGHT
- Bill of Materials (including all add-on/Reorder BMs)

FILE #6 QUALITY CONTROL FILE

LEFT
- Various Quality Control Forms
- Field Adjustment Request

RIGHT
- Daily Quality Control Inspection Reports
- Quality Control Plan

FILE #7 SAFETY/ENVIRONMENT

LEFT
- Required Safety Equipment
- Stand-up Safety Lectures
- Safety Reports
- Accident Reports

RIGHT
- Safety Plan
- Highlighted EM 385
- Environmental Plan (if applicable)

FILE #8 PLANS FILE

LEFT
- Site Layout
- Shop Drawings
- Detailed Slab Layout Drawings (if required)
- Rebar Bending Schedule
- Form Material Work Sheet

RIGHT
- Project Plans

FILE #9 SPECIFICATIONS FILE

LEFT
- Technical Data

RIGHT
- Highlighted Specifications

Figure 15-1.—NCF project package outline—Continued.

A flow chart, showing the sequence of planning steps, is shown in figure 15-2. These steps are also listed in the project planning milestones list (fig. 15-3). This list is normally assigned by the operations department at the beginning of home port. Step-by-step information on how a project package is developed is outlined in the *Naval Mobile Construction Battalion Crewleader's Handbook,* COMSECOND/COMTHIRDNCBINST 5200.2X.

PROJECT DRAWINGS

In the NCF, project drawings are normally divided into the following major categories: civil, architectural, structural, mechanical, and electrical.

Regardless of the category, project drawings serve the following functions:

- They provide a basis for estimating material, labor, and equipment before construction begins.
- They provide precise instructions for construction, showing the sizes and locations of various parts.
- They provide a means of coordination between the different ratings.
- They complement the specifications; one source of information is incomplete without the other.

Pages

Most drawings have sheets/pages with designator letters (I—Index, C—Civil, A—Architectural, S—Structural, M—Mechanical, P—Plumbing, E—Electrical, and W—Waterfront). For example, as shown in figure 15-4, the sheet designating letter and page number is the 22d architectural page in a set of plans, so it is written A-22. The name, or title, of the project will be in the largest block on the page. For EO

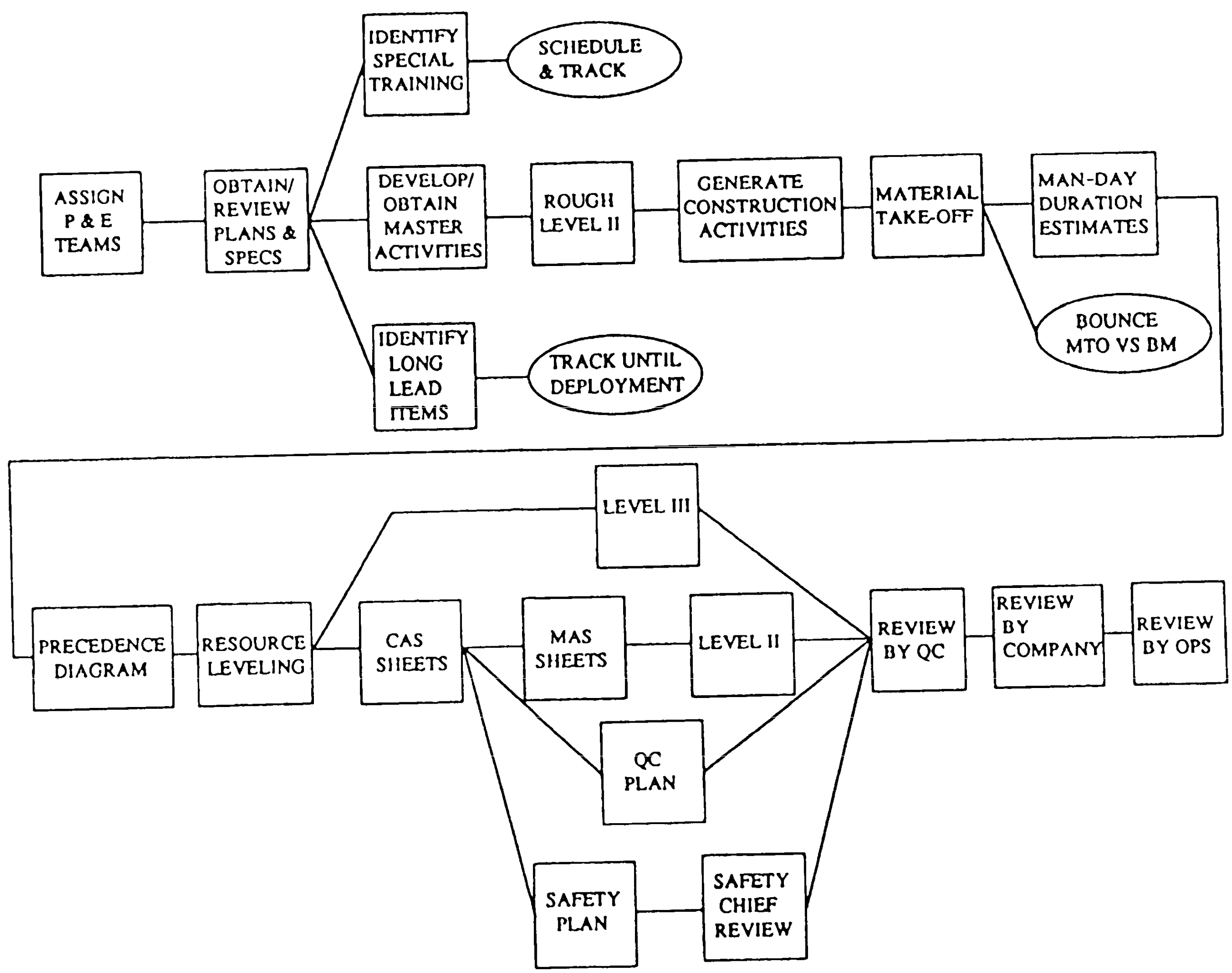


Figure 15-2.—Project planning flow chart.

PROJECT PLANNING MILESTONES

PROJECT ______________________________

	MILESTONE	DATE REQUIRED	DATE COMPLETED
1.	Designate Crew leader and Planning Team	________	________
2.	Preplanning Conference	________	________
3.	Review Plans and Specifications	________	________
4.	Identify Long Lead Materials	________	________
5.	Identify Required Skills and Training	________	________
6.	Complete Project Scope Sheet	________	________
7.	Complete Master Activity Listing	________	________
8.	Develop Level II Network	________	________
9.	Generate Construction Activity Listing	________	________
10.	Develop Independent Material Takeoff	________	________
11.	Develop BM/MTO Discrepancy List	________	________
12.	Calculate Man-days and Durations	________	________
13.	Complete Construction Activity Summary Sheets	________	________
14.	Develop Level III Network	________	________
15.	Input Network into Computer	________	________
16.	Resource Level Project	________	________
17.	Complete Master Activity Summary Sheets	________	________
18.	Develop Level II Bar Chart	________	________
19.	Consolidate Tool Requirements	________	________
20.	Consolidate Equipment Requirements	________	________
21.	Consolidate Safety Plan	________	________
22.	Consolidate Quality Control Plan	________	________
23.	Prepare Project Briefing	________	________

Figure 15-3.—Project planning milestones.

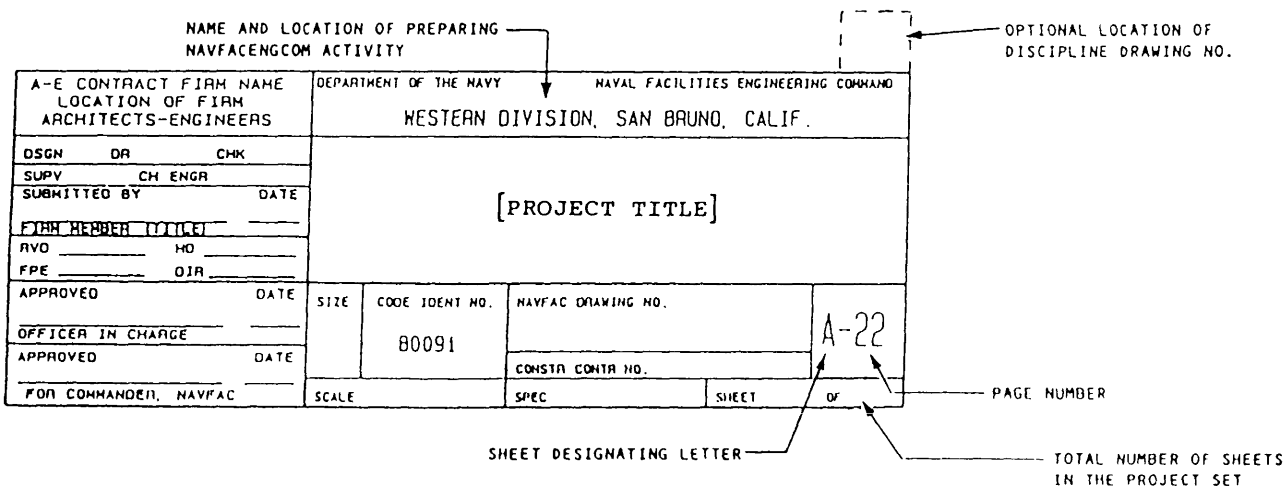


Figure 15-4.—Title block for drawings.

work, you should concentrate on the index and civil pages.

INDEX PAGE.— This page tells you where the project is located, what is in the set of drawings, and any special surveys that have been done.

CIVIL PAGES.—Civil pages encompass a variety of plans and information to include the following:

- Site preparation and site development
- Fencing
- Rigid and flexible pavements for roads and walkways
- Environmental pollution control
- Water supply units

Depending on the size of the construction project, the number of sheets/pages in a set of civil drawings may vary from a bare minimum to several sheets/pages of related drawings. Normally, on an average-size project, the first sheet/page has a location map, soil boring log, legends, and sometimes site plans and small civil detail drawings. (Soil boring tests are conducted to determine the water table of the construction site and classify the existing soil.)

A **site plan** (fig. 15-5) furnishes the essential data for laying out the proposed building lines. It shows the

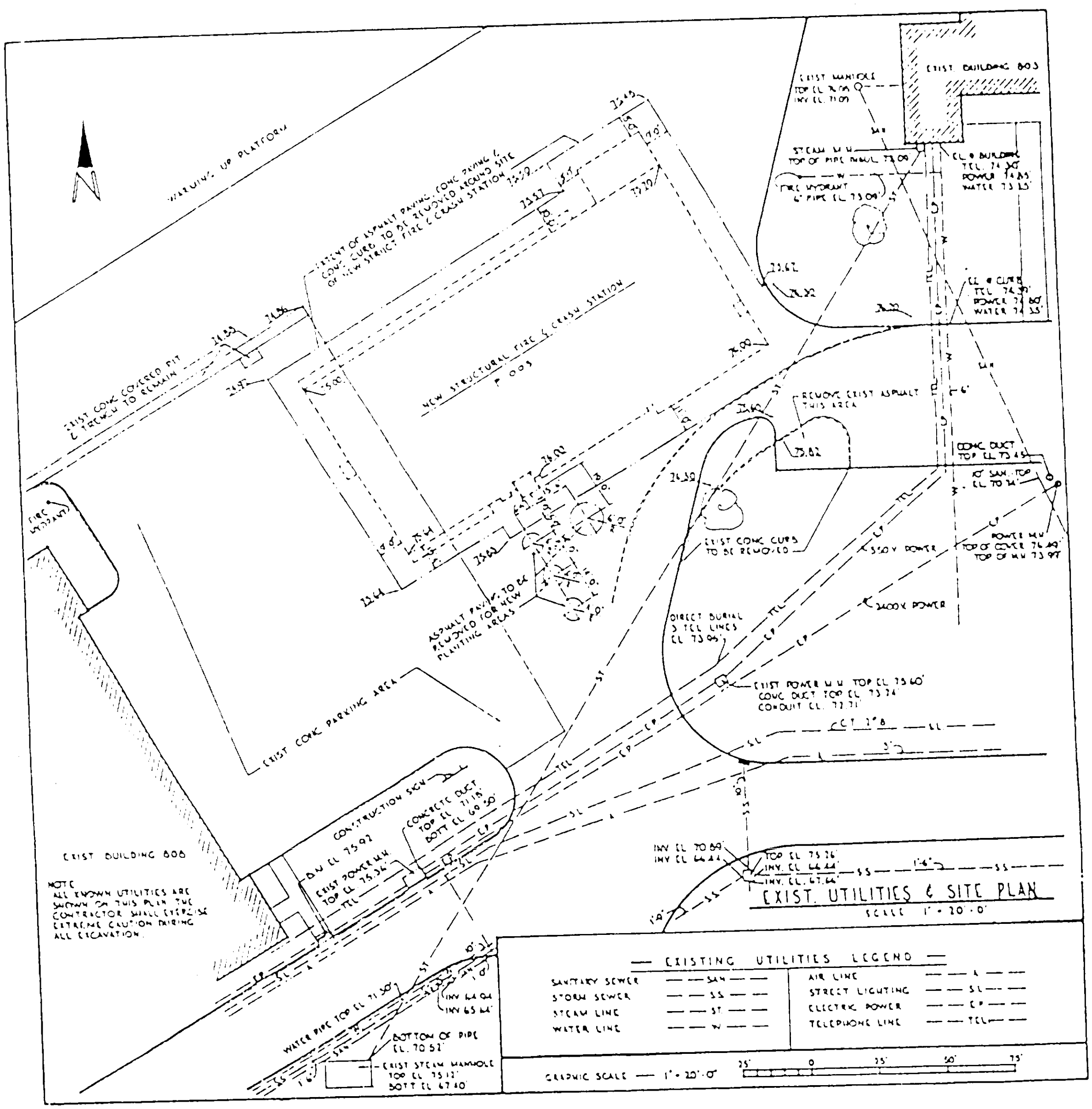


Figure 15-5.—Example of a site plan with existing utilities.

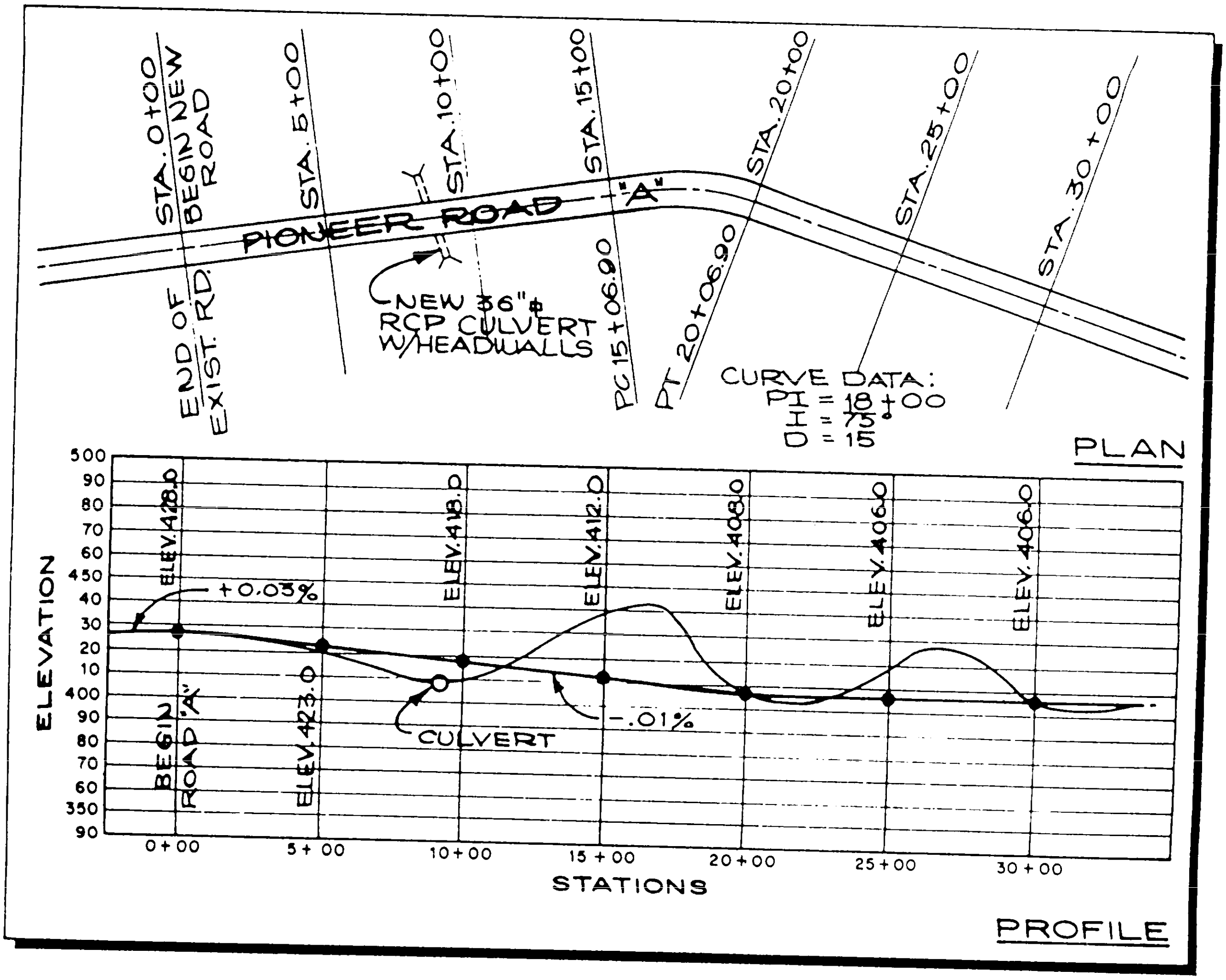


Figure 15-6.—Plan and profile sheet.

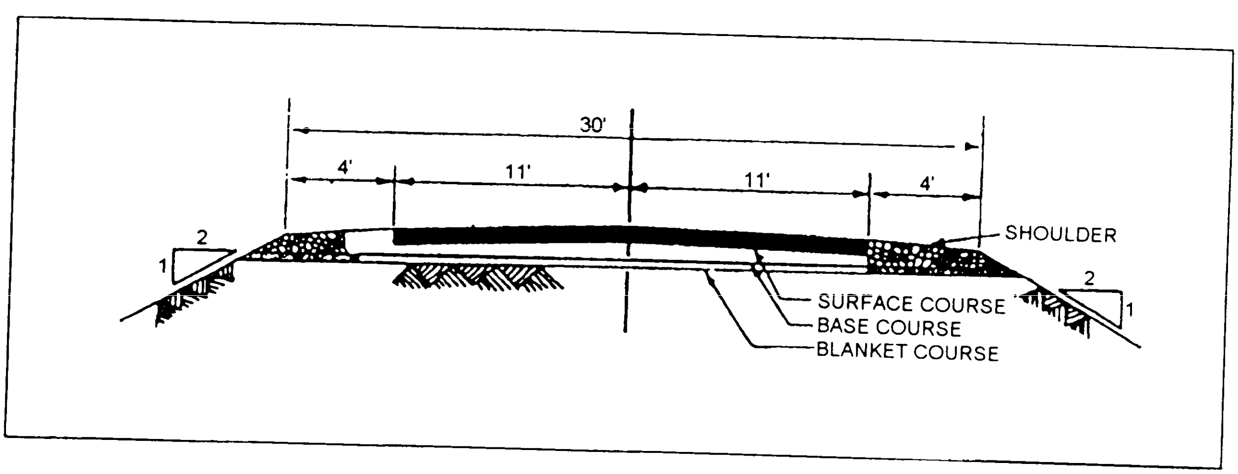


Figure 15-7.—Typical cross section.

contours, boundaries, roads, utilities, trees, structures, references, and other significant physical features on or near the construction site.

A plan and profile sheet (fig. 15-6) and a typical cross section (fig. 15-7) are other information found on a site plan.

Symbols

Symbols used in drawings are as follows:

- A **contour line** shows us an imaginary line, representing a constant elevation on the earth's surface. Blueprints, or plans, use contour lines to show the final proposed elevations.

- **Existing contour** lines identify the existing elevations (fig. 15-8). Existing and proposed elevations are used to figure cut-and-fill operations.

- **Proposed contour** lines are those we work toward, You use them to visualize the finished product (fig. 15-8).

- **Utility** symbols identify utility lines. The symbols for pipe are shown in figure 15-9. Once all the

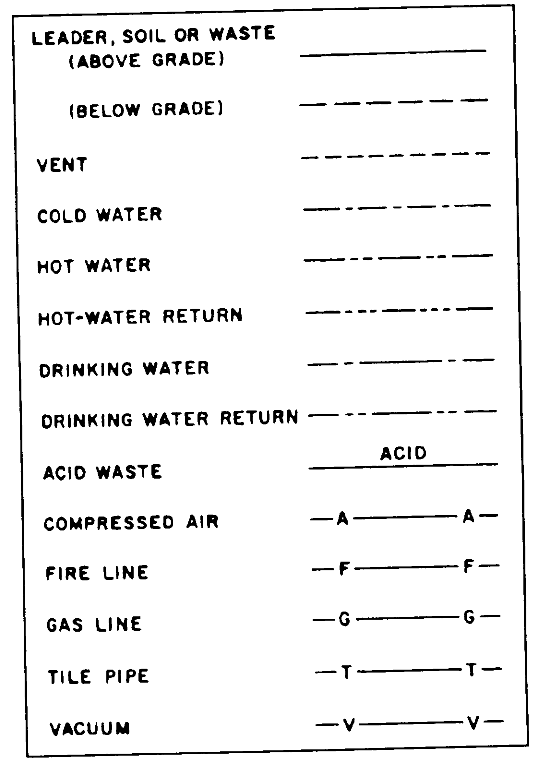


Figure 15-9.—Utility symbols for piping.

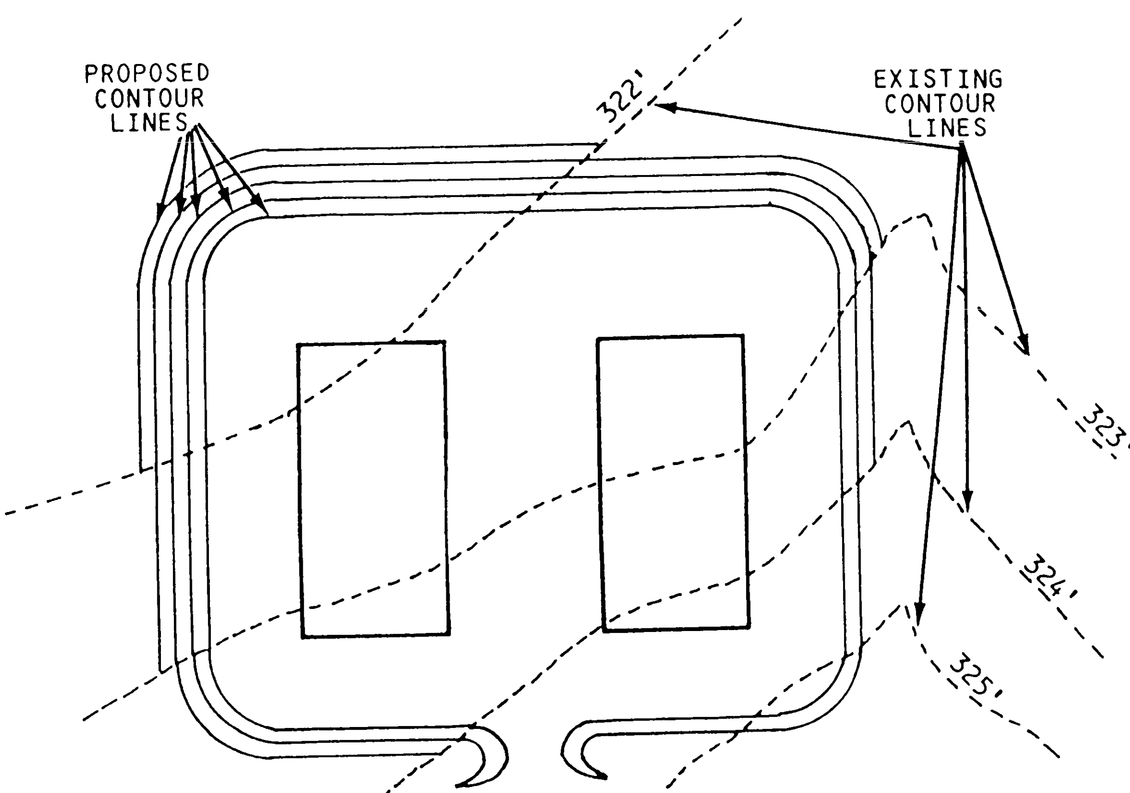


Figure 15-8.—Existing and proposed contour lines.

existing underground utilities are identified, use extreme care when working near them. Ripping up utility lines adds loss time to a project, adds to the cost of the project, and causes an inconvenience to people to whom the utilities were supporting.

NOTE: Obtain a digging permit before performing any excavations on a project.

Symbols for electric power distribution are shown in figure 15-10. Note the location of these lines not only for the reasons stated about pipe but also because of the risk of electric shock when a machine cuts an electric line.

NOTE: On some occasions certain items are mistakenly left out on new drawings. Examples are buried telephone cables, electrical lines, waterlines, and fuel lines. Because of this, you must make it a practice to compare older drawings with new drawings and to your freehand sketches.

Symbols for building material are shown in figure 15-11. These symbols are used in cross sections or cutaway views. They also label material as **new** or **existing.**

Sketches

A **freehand sketch** is a drawing, made without the use of mechanical aids or devices. Sketches may be drawn on graph paper, traced, or drawn with a straightedge. A sketch may be of an object, an idea, or a combination of both. The ability to make quick, accurate sketches is helpful in conveying your ideas to others.

Two examples of freehand sketches are shown in figures 15-12 and 15-13. These sketches were

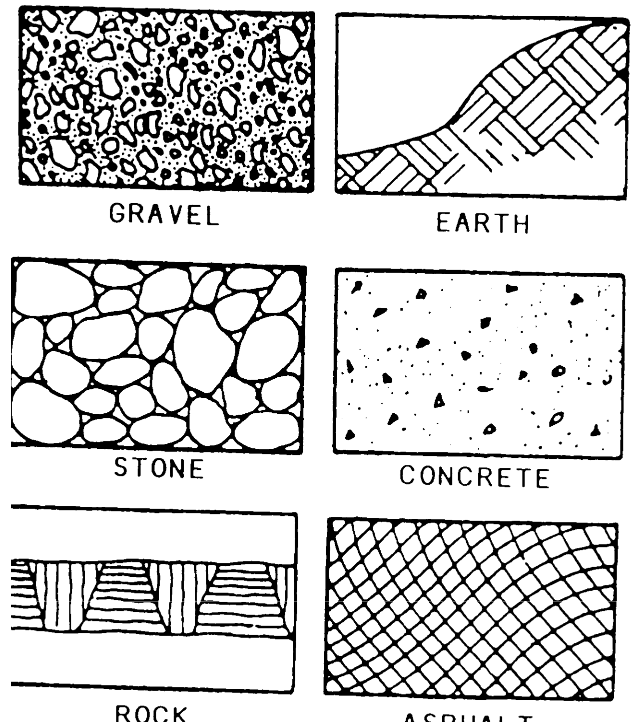


Figure 15-11.—Material symbols.

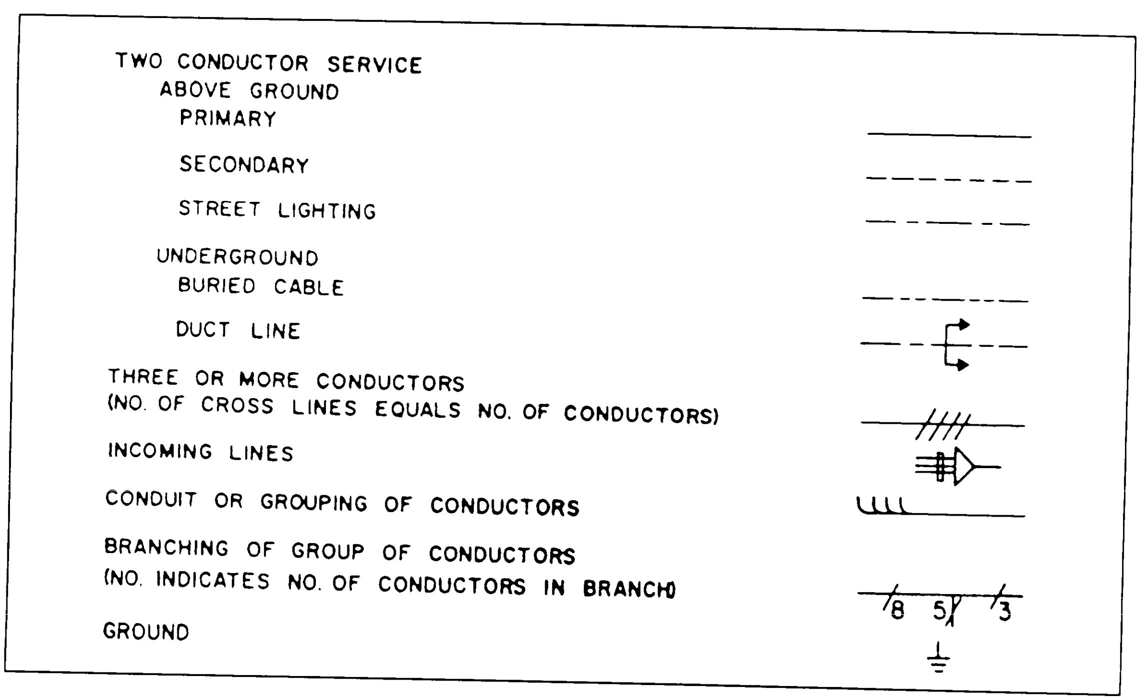


Figure 15-10.—Electrical power distribution symbols.

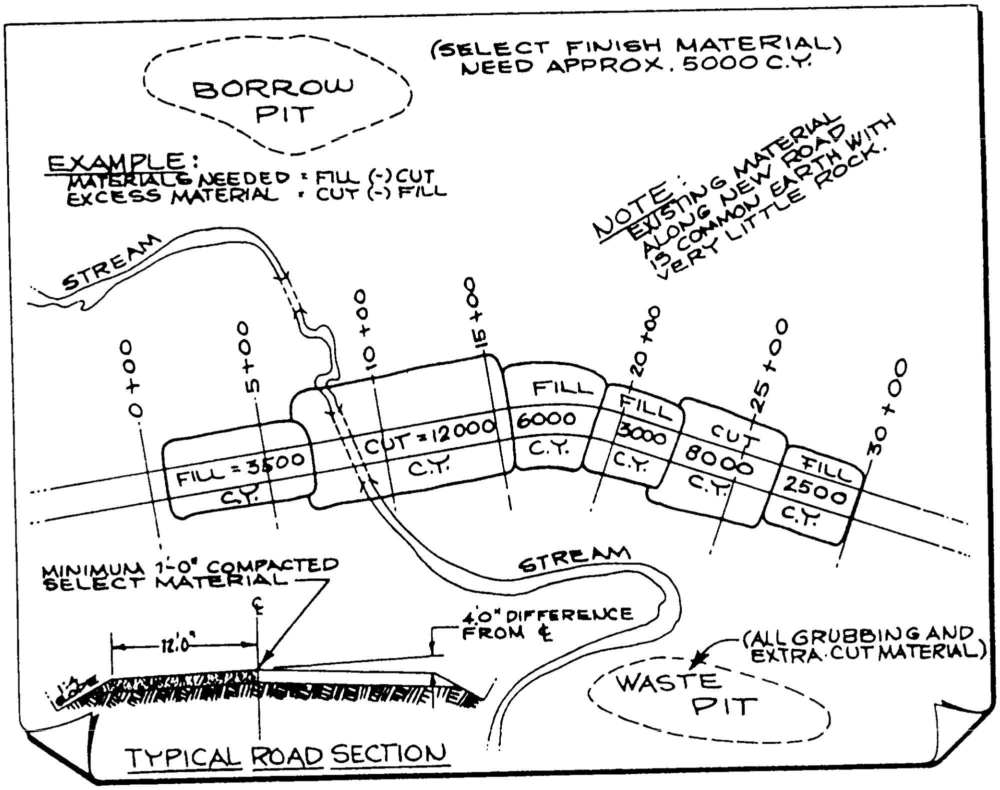


Figure 15-12.—Overlay plan sketch, emphasizing cut-and-fill areas.

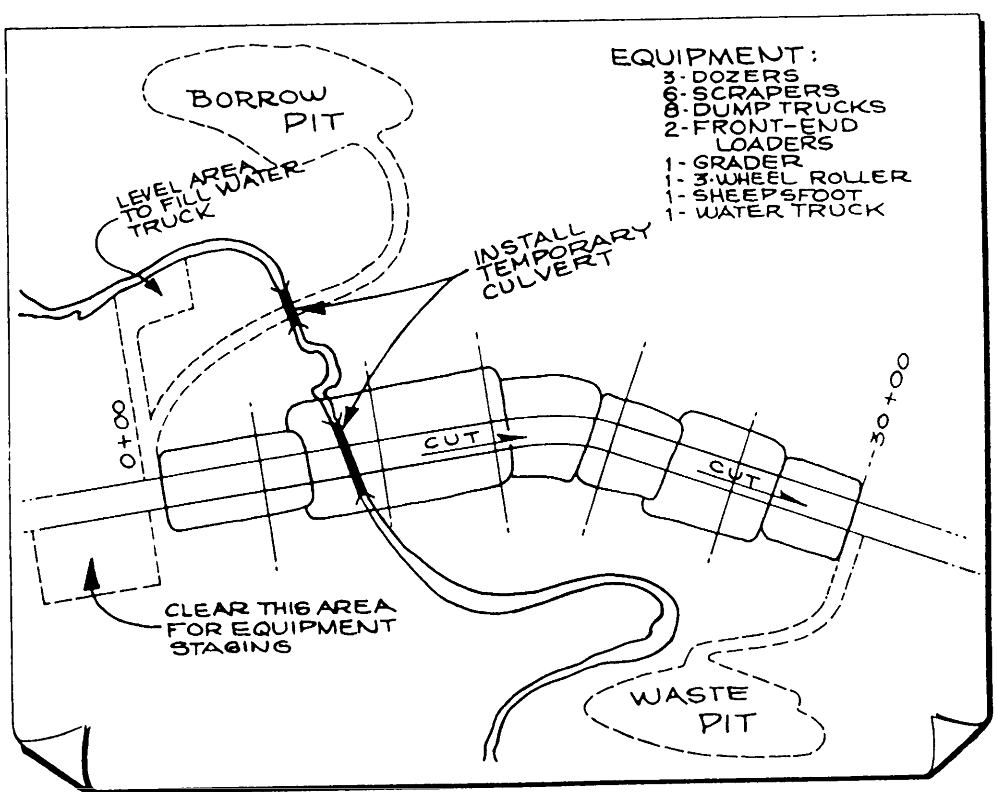


Figure 15-13.—Overlay sketch, emphasizing temporary road and culvert.

developed from the original plan and profile sheet of a typical road project. They depict different earthwork phases to be considered by the EO when engaged in earthmoving operations.

The sketches shown in figures 15-12 and 15-13 were prepared by placing a piece of tracing paper directly over the plan and profile sheet and tracing the new road and stations. Information was added that was not included on the original plan and profile sheet, such as borrow pit, waste pit, stream, temporary haul road, temporary culverts, equipment area, planned cut-and-fill areas, and a typical road section. Any information may be included that allows you to visualize the finished product.

EARTHWORK COMPUTATIONS

Earthwork computations are the calculations of earthwork volumes or quantities to determine final grades, to balance cut and fill, and to **PLAN** the most economical movement of material.

Volume Changes

Most earthmoving is computed in cubic yards; however, on some project drawings, the metric system is used. A cubic yard is a cube 3 feet long, 3 feet wide, and 3 feet high. Many dimensions in field measurements and contract plans are in feet, so if they are multiplied together to obtain bulk (length x width x depth), the results are in cubic feet. To obtain cubic yards from cubic feet, divide the cubic feet by 27 (there are 27 cubic feet in one cubic yard). It is also possible to divide the original linear measurement by 3 to convert the numbers to into yards, and then multiply. However, this may lead to working in fractions, decimals, and mixed numbers.

Cubic yards of material are either **in place, loose,** or **compacted.** Material, excavated from its natural state, increases in volume, commonly known as **swell.** Undisturbed material is measured as **in-place cubic yards,** material loosen by handling is measured in **loose cubic yards,** and the volume of compacted material is measured as **compacted cubic yards.**

NOTE: When calculating estimates from project drawings, you estimate **cuts as in-place cubic yards** and estimate **fills as compacted cubic yards.**

To calculate the correct amount of material to be handled, you convert the present soil conditions by using table 15-1.

Road Nomenclature

A cross-sectional view of a road and its components is shown in figure 15-14. Before any construction is performed on a project site, the elevation is known as **existing grade.** The driving

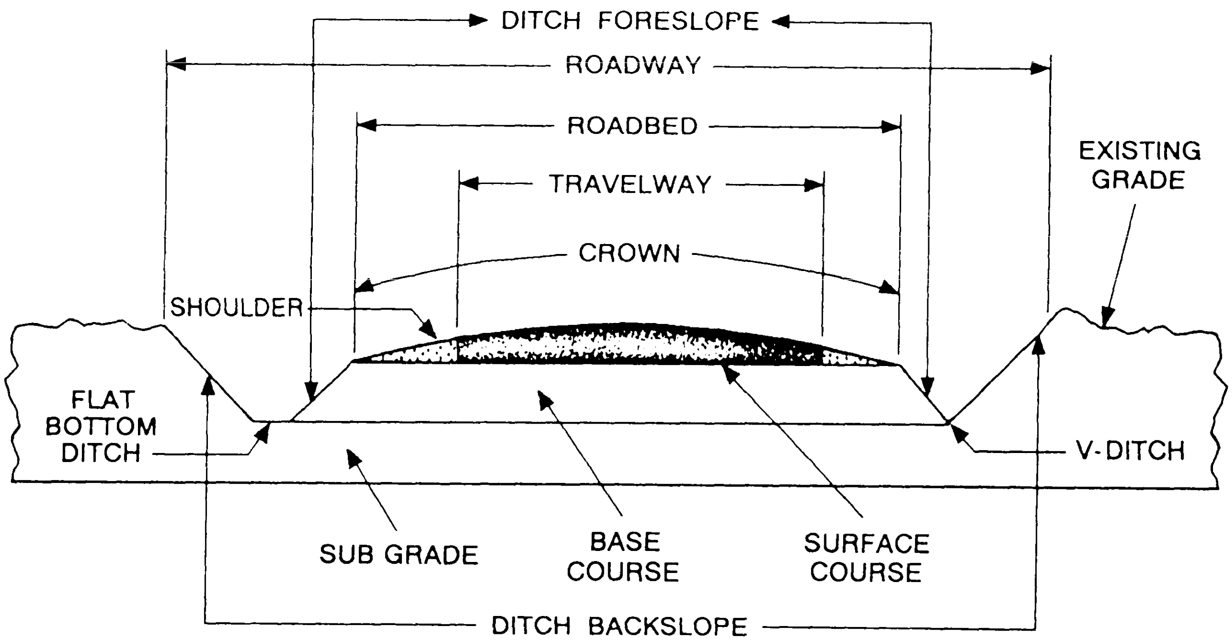
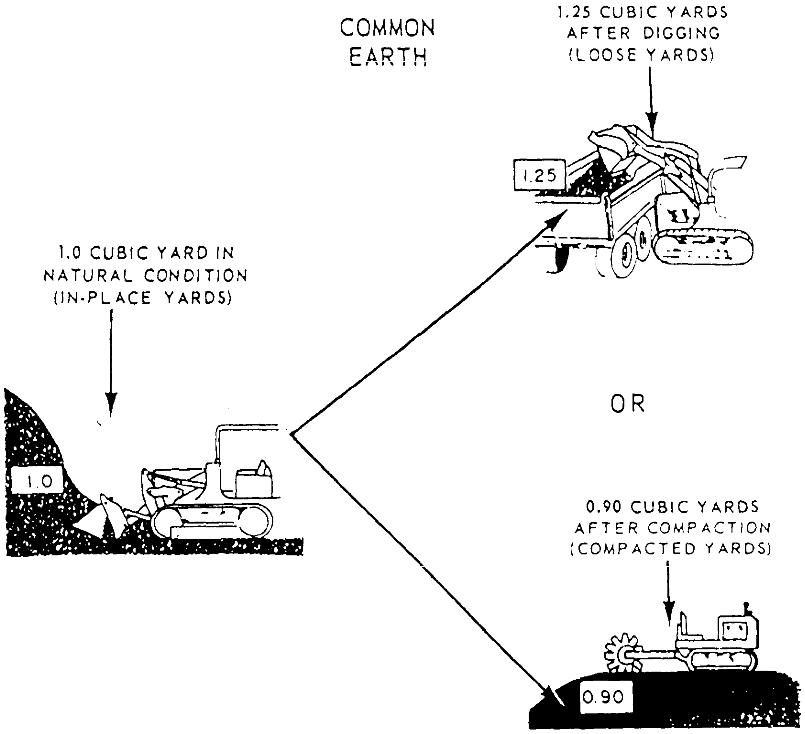


Figure 15-14.—Road nomenclature.

surface of an existing road that is to be replaced is also known as the **existing grade.** The **subgrade** of a road is a prepared base for the placement of base-course materials. The **base course** is a select layer of well-compacted soil that is placed in compacted lifts on top of the subgrade. This compaction can be accomplished by mechanical stabilization or chemical stabilization. The **surface course** and the **shoulders** complete the road. The surface course is usually concrete or asphalt and is part of the road that vehicles travel on. The shoulder of the road performs as a retainer on each side of the surface course and provides an emergency parking area.

The **crown** of the road is an established slope from the center line of a roadbed to the outside of the shoulders and allows for excess water to drain from the surface into either a **V type** or **flat bottom type of ditch.** The area that covers the entire width of the road

Table 15-1.—Volume Changes



SOIL TYPE	PRESENT SOIL CONDITION	CONVERTED TO:		
		INPLACE	LOOSE	COMPACTED
SAND	INPLACE	1.00	1.11	0.95
	LOOSE	0.90	1.00	0.86
	COMPACTED	1.05	1.17	1.00
COMMON EARTH	INPLACE	1.00	1.25	0.90
	LOOSE	0.80	1.00	0.72
	COMPACTED	1.11	1.39	1.00
CLAY	INPLACE	1.00	1.43	0.90
	LOOSE	0.70	1.00	0.63
	COMPACTED	1.11	1.59	1.00
ROCK	INPLACE	1.00	1.30 - 2.00	1.25 - 1.50
	LOOSE	0.50 - 0.77	1.00	0.75 - 0.96
	COMPACTED	0.67 - 0.80	1.04 - 1.33	1.00

project, including the ditches, is known as the **roadway.** The **roadbed** is the section that includes the surface course and both shoulders, and the **travel way** is the surface course that the vehicle travels on.

Slope Ratio

The two most common slopes used in road construction are the **foreslope** and **backslope.** The foreslope extends from the outside of the shoulder to the bottom of the ditch. The backslope extends from the top of the cut at the existing grade to the bottom of the ditch. The amount of slope in a foreslope or backslope is the ratio of horizontal distance to vertical distance (fig. 15-15). That means that for every one (1) foot of vertical (up or down), the horizontal distance changes proportionally. The following are equations to compute slope ratio:

1. If the base and the height are known factors, but not the slope, use the following:

$$Base \div Height = Slope$$

$$(B + H = S$$

2. If the slope ratio and the height are known factors, but not the base, use the following:

$$Slope \times Height = Base$$

$$(S \times H = B)$$

3. If the base and the slope ratio are known factors, but not the height, use the following:

$$Base \div Slope = Height$$

$$(B \div S = H)$$

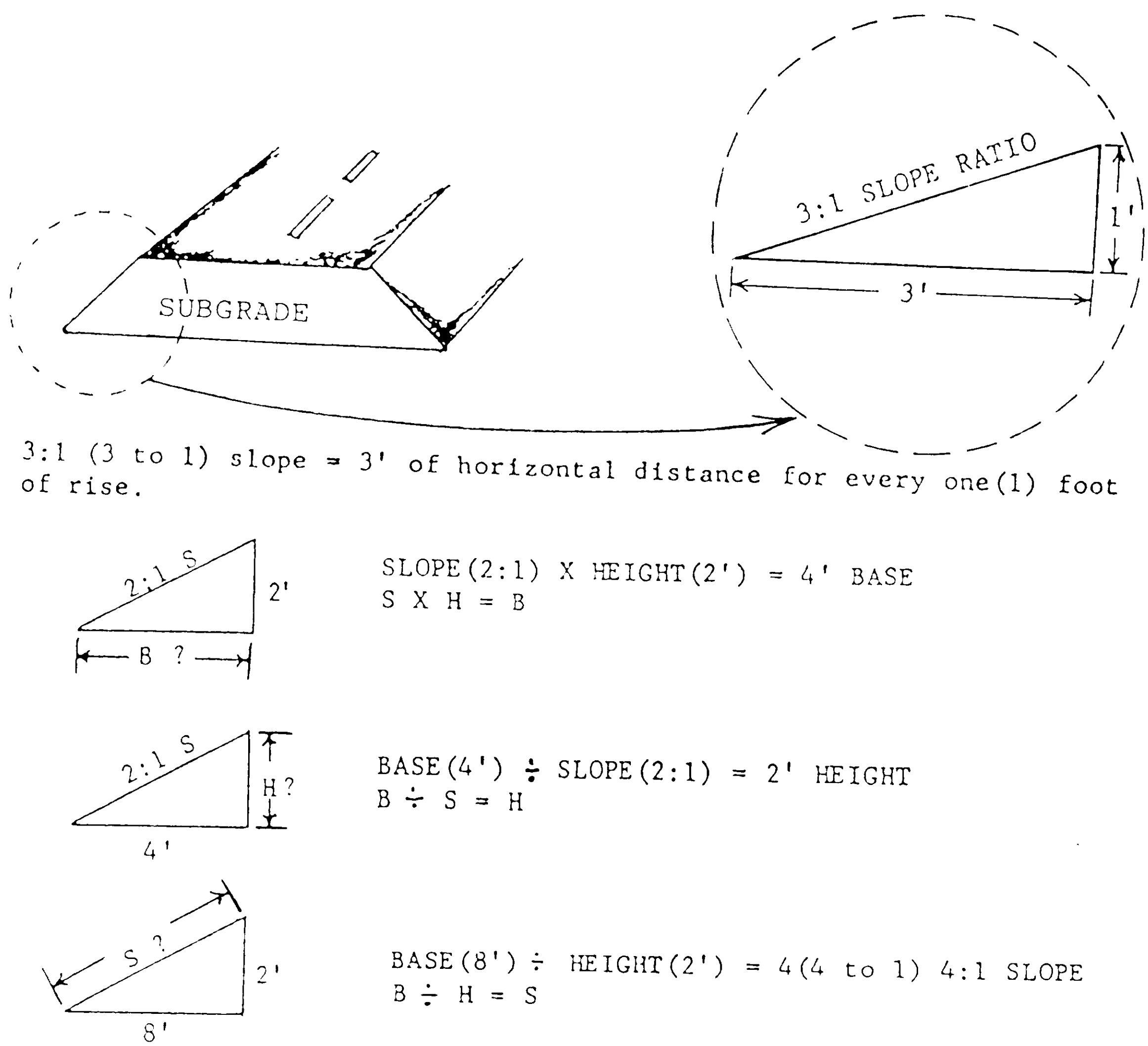


Figure 15-15.—Slope ratio.

Cross Sections

A **cross-sectional view** (fig. 15-16) that is given for a road project is a cutaway end view of a proposed station between the left slope and the right slope. Typical cross sections are plotted at any intermediate place where there is a distance change in slope along the center line where the natural ground profile and grade line correspond. The cross section displays the slope limits, the slope ratio, and the horizontal distance between centerline stakes and shoulder stakes. It also shows the vertical distance of the proposed cut or fill at the shoulder and centerline stakes.

To compute the area of a cross section, you must first break it down into geometric figures (squares, triangles, etc.). (See fig. 15-17.) Compute each area separately, then total the results to obtain the total **square feet.**

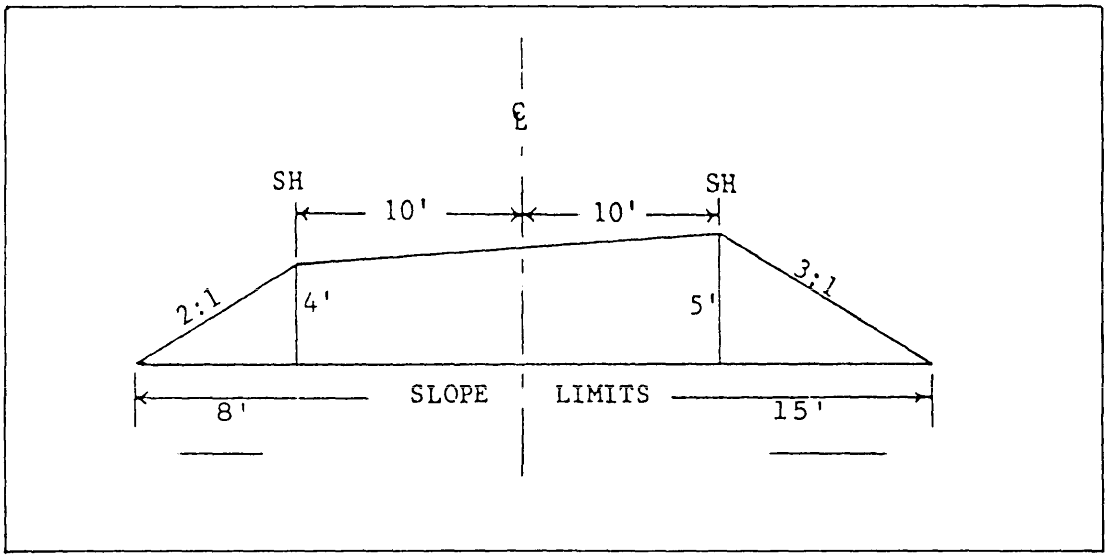


Figure 15-16.—Cross section.

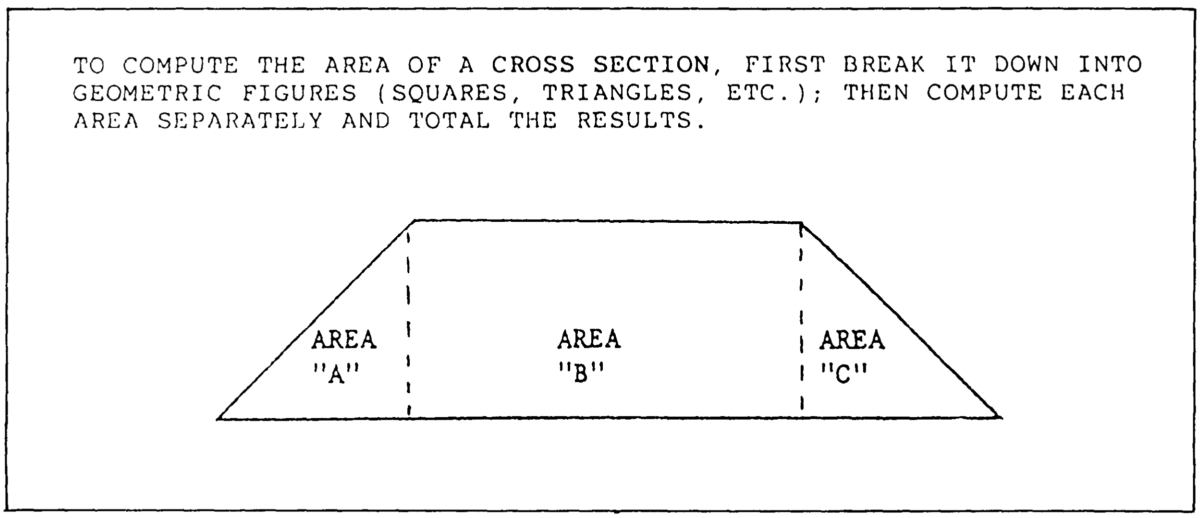


Figure 15-17.—geometric sections of a cross section.

To compute the square feet area of a SQUARE or RECTANGLE (fig. 15-18), use the following equation:

Area = Base x *Height* or *(A = B x H).*

Since a RIGHT TRIANGLE is a square or rectangle cut in half diagonally, the same equation can be used to compute the area and the result divided by 2 (fig. 15-19). For example,

$$\textit{Triangle area in square feet} = \frac{Base \times Height}{2}$$

or $B \times H \div 2$ = Triangle area in square feet

Another geometric figure you may encounter in a cross section is a TRAPEZOID (fig. 15-20). The equation to compute the area of a trapezoid is as follows:

$$\textit{Trapezoid Area in square feet} = \left(\frac{H_1 + H_2}{2}\right) \times L$$

or H_1 = Height of one side

+ H_2 = Height of other side

$Sum \div 2 \times Length$ = Trapezoid area in square feet.

The next step is to compute the total area in the cross section (fig. 15-21). This is accomplished by adding the results of each geometric figure in the cross

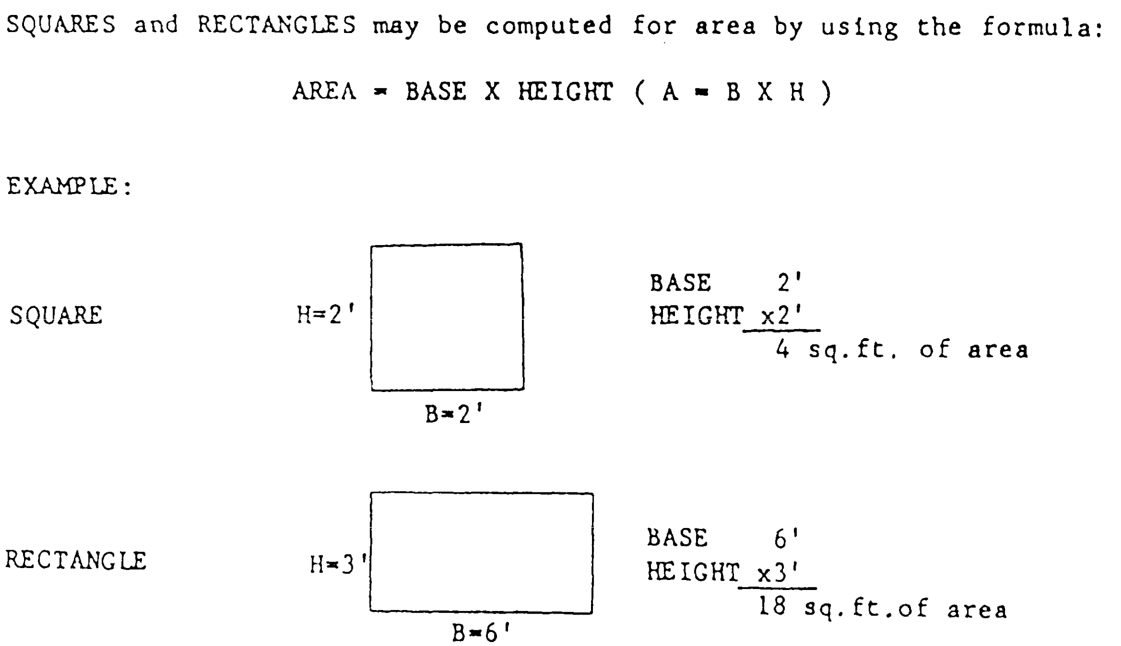


Figure 15-18.—Area of a square and rectangle.

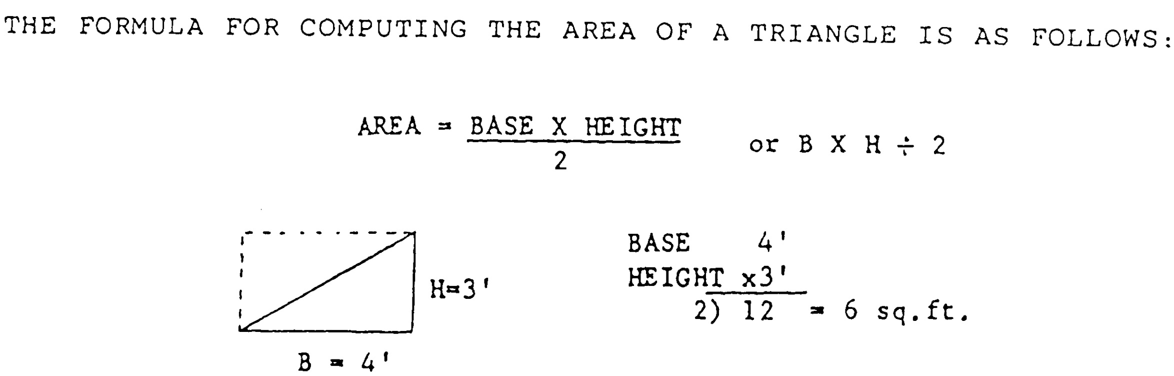


Figure 15-19.—Area of a triangle.

section. This value is the total end area of the cross-sectional view.

To compute the amount of cubic yards between two cross sections, use the following equation:

$$(A_1 + A_2) \times 1.85 \times \mathit{Distance} = \mathit{Cubic\ yards}$$

A_1 = Area of one end cross section

A_2 = Area of other end of cross section

1.85 = Constant factor

D = Distance between two end areas that must be changed to a decimal form; for example, 250 feet = 2.50, 125 feet= 1.25,75 feet= .75, and so forth

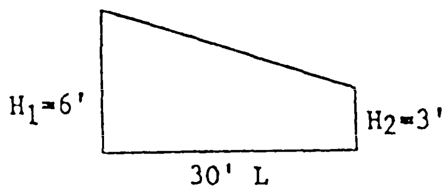
To compute the equation, take the area of one end section (cross section) plus the area of the other end and multiply the sum of the two areas by a constant factor of 1.85. This value should now be multiplied by the distance between the two end areas to determine the number of cubic yards. (See fig. 15-21.)

CONSTRUCTION (GRADE) STAKES

Grade work is the plotting of irregularities of the ground (making cuts or fills) to a definite limit of grade (elevation) and alignment. This is performed by reading information placed on construction (grade) stakes.

THE FORMULA FOR COMPUTING THE AREA OF A TRAPEZOID IS AS FOLLOWS:

$$\text{AREA} = \frac{H_1 + H_2}{2} \times L$$



H^1 = 6'

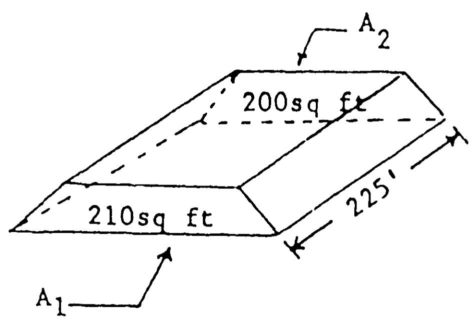
H^2 = +3'

2) 9 = 4.5 x 30' = 135.0 sq.ft.

Figure 15-20.—Area of trapezoid.

THE FORMULA FOR COMPUTING CUBIC YARDS IS AS FOLLOWS:

$(A_1 + A_2)$ 1.85 x DISTANCE = CUBIC YARDS



A_1 =	210	sq ft
A_2 =	+200	sq ft
	410	
	x1.85	FACTOR
	2050	
	3280	
	410	
	758.50	
	x2.25	DISTANCE
	379250	
	151700	
	151700	
	1706.62~~5~~0	
	1706.63	CUBIC YARDS

Figure 15-21.—Computing cubic yards of cross sections.

Construction stakes, sometimes referred to as **grade stakes,** are the guides and reference markers for earthwork operations to show cuts, fills, drainage, alignment, and boundaries of the construction area. The number of stakes and the information contained on them will vary with the project as to whether they are temporary or permanent. Stakes are usually placed by a three- to five-person survey party using a level, a level rod, a tape, and range poles.

A **"stake"** is defined as any wooden lath, stake, or hub. **"Hub stakes"** are 2 inches by 2 inches by approximately 12 inches and are used primarily for well-defined surveyors' reference points, with the red and blue tops used in finished grade work. Stakes will vary in shape and size according to their use and the materials available for their manufacture. Several stakes are shown in figure 15-22. Stakes range in size from the ordinary rough plaster lath to 1- by 2- by 3-inch cross-sectional lumber with lengths varying from 18 inches to 48 inches.

All reference hubs, markers, and bench marks established by the Engineering Aids (EAs) for project control or alignment are protected by **guard stakes. Guard stakes** are used as a means of locating the points needed. Some color of bunting or flagging (a narrow strip of cloth or plastic) may be tied around the top of the stake. Station identification is placed on the front of the stake and any other pertinent data on the back.

In some situations, the survey crew will establish grades only on the centerline stakes, while edge-of-road and slope stakes are set by the project supervisor and helpers. Alignment, shoulder, and slope stakes should be 1 inch by 2 inches in cross section, smooth on four sides, and about 2 feet in length. Actual grade desired is indicated by a reference mark, called a crowfoot, and numbers to show the amount of cut or fill.

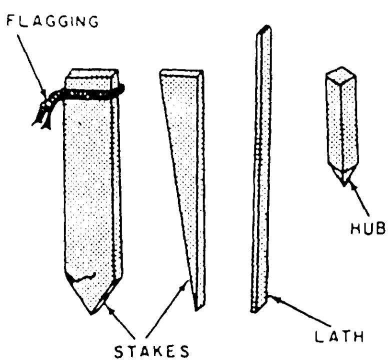


Figure 15-22.—Types of stakes.

These stakes should be marked with the following information:

- The stationing or location of any part of the road, runway, or taxiway relative to a starting point or reference
- The amount of cut and fill from the existing ground surface or reference mark on the stake
- The distance from the center line to the stake location and from the center line to the ditch line

In most earthwork, measurements are made and written by the decimal system as used in construction engineering. Most markings on construction stakes will be in feet and tenths of a foot. A stake marked $C3^5$ means that a cut must be made 3.5 feet. To convert .5 foot to inches, multiply the decimal fraction by 12. For example: .5 x 12 inches = 6 inches; .25 x 12 inches = 3 inches.

STARTING POINT

The **"starting point"** of a survey is also called the **starting station** and is numbered 0 + 00. The next station is 100 feet farther away and is numbered 1 + 00. The next station, which is 200 feet beyond the starting point, is then numbered 2 + 00, and so forth. All stations that end with 00 are called **full stations.** As shown in figure 15-23, stations may be abbreviated **STA** on the stakes.

On sharp curves or on rough ground, the stakes may be closer together than on the straightaway. Stations, located at a distance shorter than 100 feet from the preceding station, are known as **plus stations,** such as

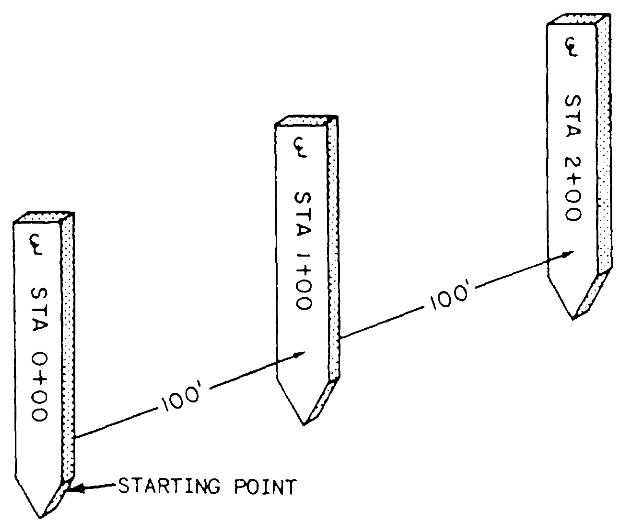


Figure 15-23.—Starting point.

3 + 25, 3 + 53, and 3 + 77. These examples are plus stations of station 3 + 00.

LINE STAKES

Line (or alignment) stakes mark the horizontal location of the earthwork to be completed and give the direction of the proposed construction. Running over stakes or otherwise damaging the stakes before they have served their purpose results in many hours of extra work to replace them and delay in the completion of the project. **Rough alignment stakes** are placed far ahead of the clearing crew to mark boundaries of the area to be cleared and grubbed. These stakes, or markers, are not of a control nature and their loss is expected. On some stakes, the alignment information and the grade requirement are combined on the same stake (fig. 15-24).

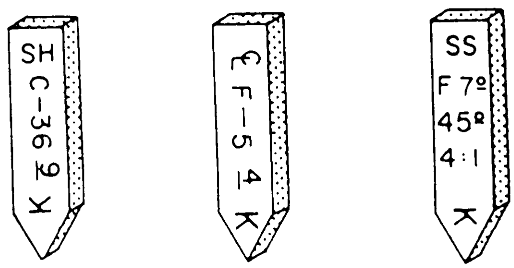


Figure 15-24.—Combined alignment and grade stake.

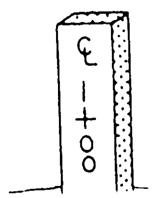


Figure 15-25.—Centerline stake

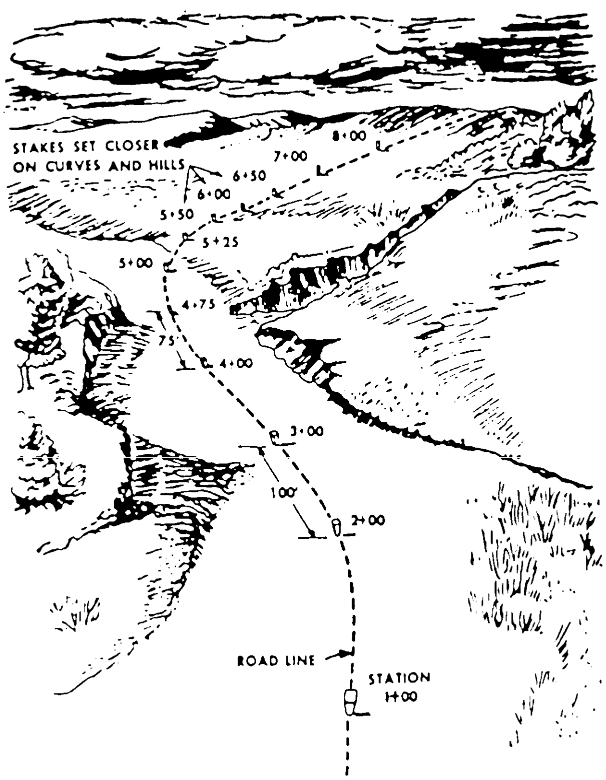


Figure 15-26.—Station numbers.

Centerline Stakes

Stakes set along the center line of a project are known as **centerline** stakes and are identified by letters, as shown in figure 15-25. Most stakes are marked on both the front and back.

On centerline stakes, the station number is written on the front of the stake, such as 0 + 00, 1 + 00, 4 + 75, and 5 + 25 (fig. 15-26).

The required grade is always established at the center line of the project. The amount of change in elevation is written on the back of the centerline stake with a **cut-** or- **fill** symbol, which is known as the crow-foot (fig. 15-27). The **"crowfoot"** is the reference point of the vertical measure or grade.

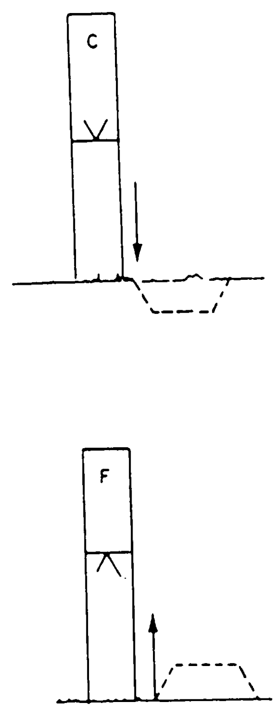


Figure 15-27.—Cut-and-fill crowfoot symbol.

Shoulder Stakes

Stakes that are set on a line parallel (same direction and interval) with the center line are called **shoulder stakes** and are identified by the symbol **SH** at the top of the stake (fig. 15-28).

Shoulder stakes mark the outer edge of the shoulders and are set with the broad side facing the center line of the road on the shoulder line. Shoulder stakes carry the same station number as the centerline stake they are set to, but the station number is placed on the **back of the stake** (the side facing away from the center line). The amount of cut or fill is marked on the side of the shoulder stake facing the center line (front) and represents the amount of cut or fill required at that location. The horizontal distance from the shoulder stake to the center line is sometimes placed beneath the cut-or-fill figure. The basic difference between centerline stakes marked with the ℄ symbol and shoulder stakes marked **SH** is (1) centerline stakes are set along the center line of the project and (2) shoulder stakes are set parallel with the center line defining the shoulder of the road or runway and face the center line (fig. 15-29).

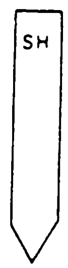


Figure 15-28.—Shoulder stake symbol.

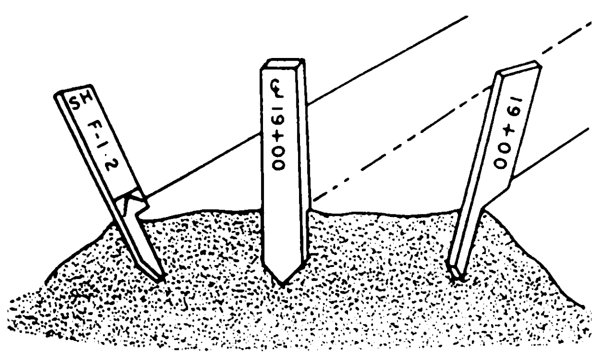


Figure 15-29.—Center line and shoulder stakes.

Cut-and-Fill Stakes

Lowering the elevation of a grade is known as making a **cut. Cut stakes** are designated by the letter **C** written on the stake. The numerals, following the letter **C,** indicate the amount of ground to be cut to obtain the desired grade and are measured from the crowfoot down.

Raising the elevation of the ground is known as making a **fill.** A **fill stake** is designated by the letter **F** written on the stake. The numerals that follow the letter **F** indicate the amount of ground material needed to bring the existing ground to the desired grade and are measured from the crowfoot mark on the stake up.

In going from a cut to a fill or vice versa, there may be one or more stakes representing points on the

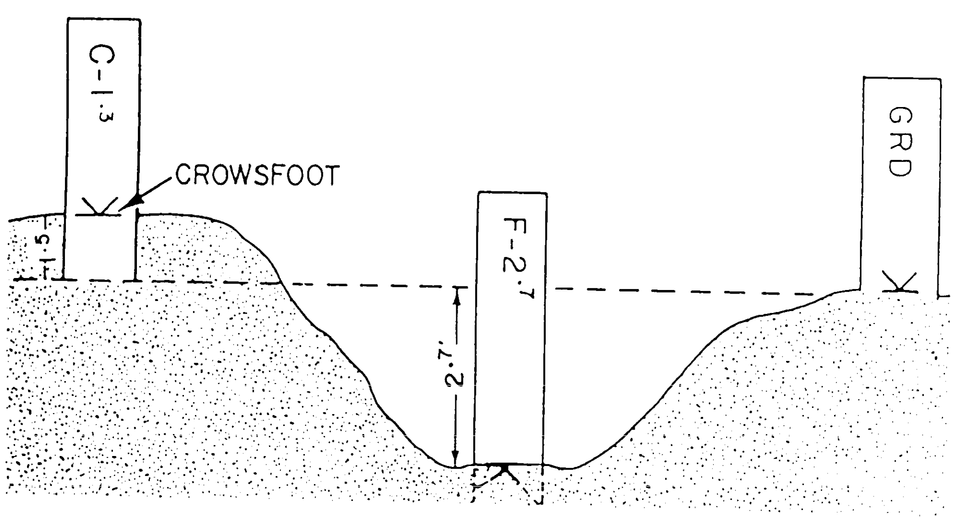


Figure 15-30.—Cut, fill, and on-grade stakes.

desired grade, as shown in figure 15-30. These stakes are marked with **GRADE,** or **GRD,** and a crowfoot mark even with the desired grade.

Basically, the difference in cut, fill, or on-grade stakes is as follows:

- Cut stakes indicate a lowering of the ground or elevation.
- Fill stakes indicate raising the ground or elevation.
- On-grade stakes indicate the ground is at the desired grade and does not need a cut or fill.

Offset Stakes

After a survey of a project has been completed and the stakes are set and marked, the required amount of work needed to complete the job is determined by using the information on these stakes. Since this information has to be used often during construction and the original stakes can be destroyed or covered up by carelessness or inexperienced operators, it is necessary to document this information.

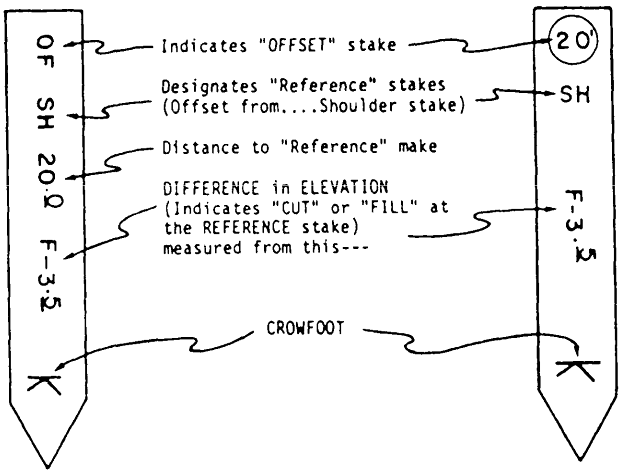


Figure 15-31.—Reference information found on a offset stake.

To prevent the loss of reference information, you should transfer the required information from the stake located in the immediate area of construction to a new stake. Set this stake far enough away so that it will not be damaged or destroyed by equipment being operated in the construction area. This new stake is called an **offset stake** and is identified by the symbol **OF** or an **O** (fig. 15-31).

You should note the number of linear feet that separates the offset stake from the original reference stake. This is written on the offset stake below the **OF** or within the circle, followed by the amount of cut or fill, in feet, which may be required. A stake marked "OF 35′CL C-1º" means that the stake is offset 35 feet from the centerline stake and that a cut of 1 foot is required to attain the desired final grade.

The difference in elevation must be noted on the offset stake. The symbol, representing the stake from which the information was originally transferred, is also noted on the offset stake. If the offset stake was offset from a shoulder stake, the symbol would be **SH** instead of ℄.

The amount of cut or fill, if any, must be noted on the offset stake. However, because of existing terrain, this information on the offset stake may not be the same as that on the original stake. In figure 15-32, you can see that the offset stake reads for a cut to be made to reach a desired elevation at the center line, while a

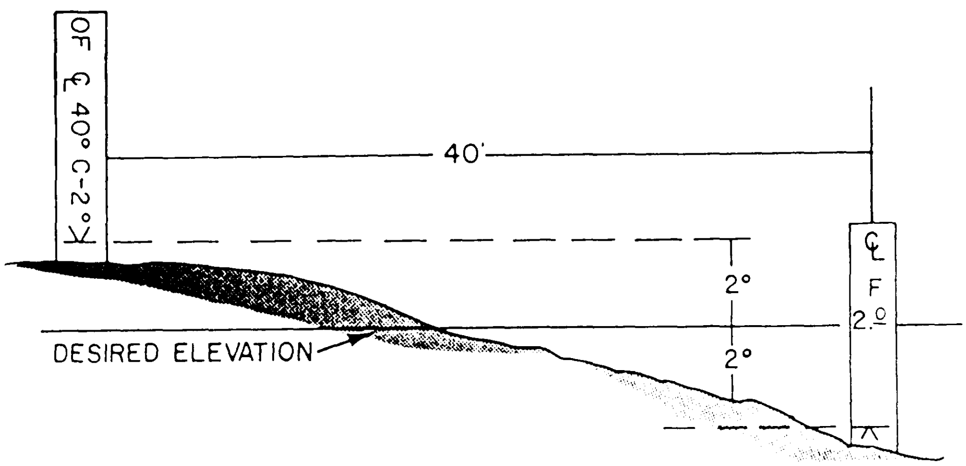


Figure 15-32.—Difference in elevation between the offset stake crowfoot and desired grade at center stake.

centerline stake would be marked for a fill to reach the same elevation.

Slope Stakes

The identification markings on slope stakes may vary according to survey parties; however, the symbol **SS** is the most commonly used slope stake symbol. The information normally found on a slope stake (fig. 15-33) is any cut-or-fill requirements, the distance from the center line, and the slope ratio. When it becomes necessary to offset the slope stake, the offset distance from where the slope stake should be is written at the bottom of the offset stake.

Slope stakes indicate the intersection of the cut-or-fill slope with the existing natural groundline and limit of earthwork on each side of the center line (fig. 15-34).

Right-of-Way Stakes

Stakes set on the property line of a construction site are known as **right-of-way stakes.** These stakes mark the boundaries of the site or project. You must not operate equipment outside the property line defined by the right-of-way stakes. The right-of-way stakes are usually marked by the use of colored cloth (bunting) or flagging. Occasionally right-of-way stakes may be marked with the symbol **R/W** (fig. 15-35).

Finish Grade Stakes

When performing final grading, you are likely to work with stakes called **blue tops.** These are hub stakes, which are usually 2 inches by 2 inches by 6 inches. These hubs are driven into the ground until the top is at the exact elevation of the finished grade as determined by the surveying crew. They are colored with a blue lumber crayon (keel) to identify them as finish grade stakes. Red crayon is normally used to indicate the subgrade elevation. Blue top stakes are placed when the existing grade is within 0.2 feet (2.4 inches) above the final or desired grade. The desired grade is obtained by lowering or raising the compacted grade with a grader until it is flush or even with the top of the hub (fig. 15-36).

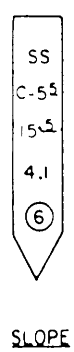


Figure 15-33.—Slope stake.

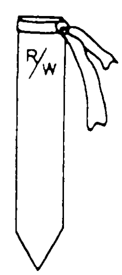


Figure 15-35.—Right-of-way stake symbol.

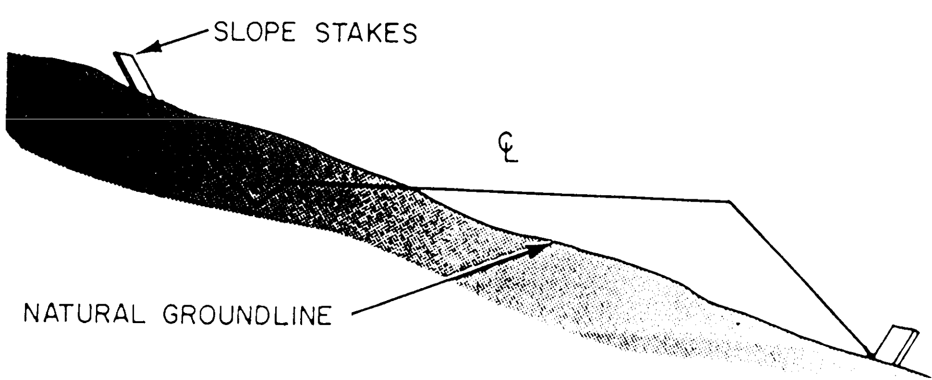


Figure 15-34.—Slope stake set in existing natural groundline.

LEVELING EQUIPMENT

To set, use, and compute grade stake measurements, you must be able to measure the vertical distance from one point to another. This process is called **leveling** and is accomplished by using leveling equipment.

A **level** is an instrument used for measuring vertical distances. All levels have a line of sight with a bubble device for maintaining the instrument in a horizontal plane. Levels vary in their accuracy according to the quality and magnification power of the lens.

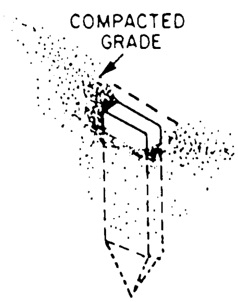


Figure 15-36.—Finish grade stake.

Vertical distances are actually measured by sighting on a graduated rod, called a **level rod.** Like other surveying equipment used for measuring distances, level rods usually are graduated in feet, tenths, and hundredths.

HAND LEVEL

The hand level is generally a round metal tube about 6 inches long with an eyepiece at one end, a cross hair at the other end, and a **level vial** on top (fig. 15-37). Part of the cross-hair end is covered with a mirror that reflects the image of the bubble to the viewer.

To use the hand level, look through the eyepiece end at the rod with the level vial on top. Tilt the entire hand level until the bubble is centered on the cross hair while looking through the eyepiece. It is sometimes necessary to know the height of the level above the ground where you are standing. This may be accomplished by resting the level on a stick of known

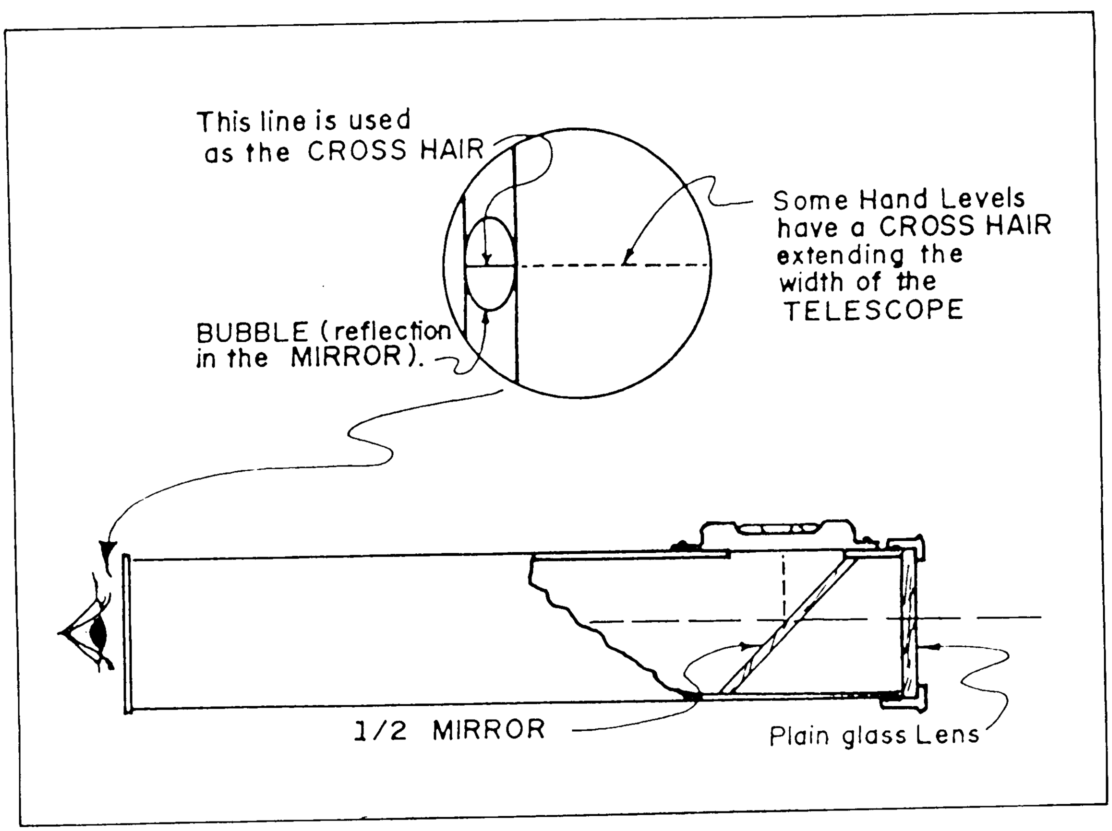


Figure 15-7.—Hand level.

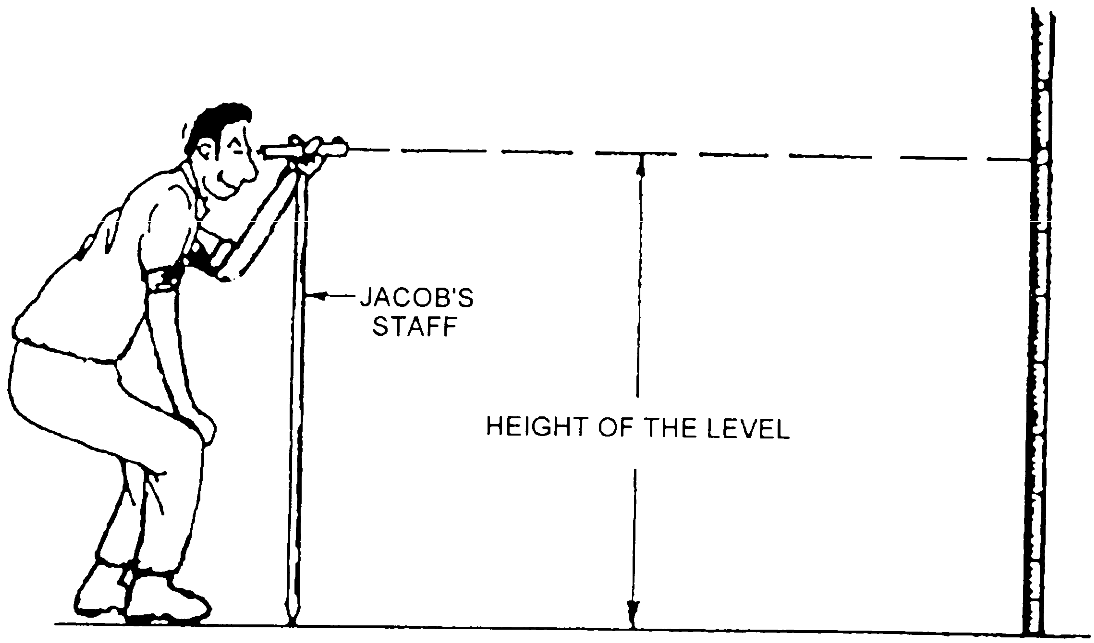


Figure 15-38.—Using a Jacob's staff with a hand level.

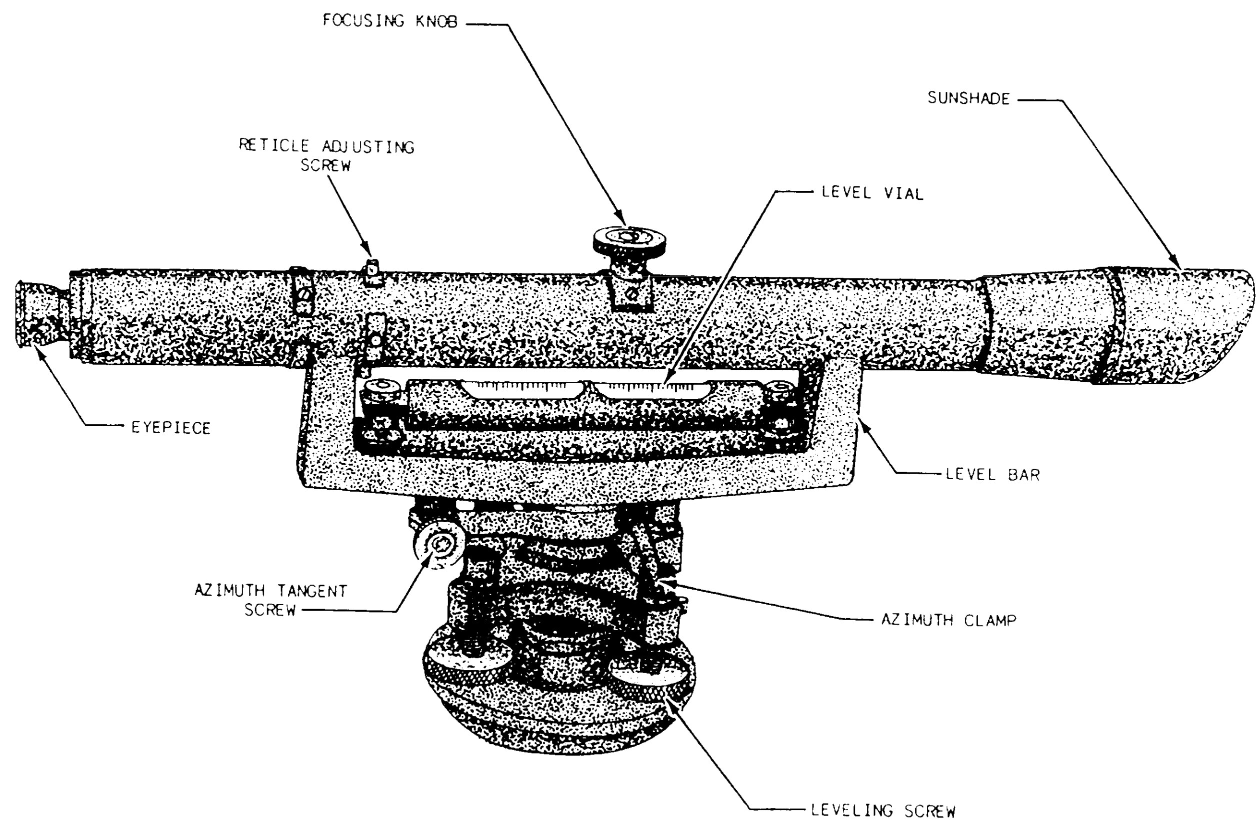


Figure 15-39.—Dumpy level.

length. This stick is known as **Jacob's staff,** as shown in figure 15-38. For rough work, you may ignore the use of a stick and merely use the height of your eye above the ground in your normal standing position.

The hand level is used for checking grade during the rough or early part of a construction project and is not used at distances greater than about 50 feet or even lesser distances if an accuracy of more than 2 or 3 tenths is required.

DUMPY LEVEL

The dumpy level (fig. 15-39) has its telescope rigidly attached to the level bar, which supports an adjustable, highly sensitive level vial. The cross hairs are brought into focus by rotation of the eyepiece and the focusing knob. The telescope can be exactly trained on the level rod by lightly tightening the azimuth clamp and manipulating the azimuth tangent screw. Depending on atmospheric conditions, the dumpy level can be used to measure vertical distances accurately at distances of 300 feet or less. When used for alignment, it is accurate at distances up to 1,000 feet.

SELF-LEVELING LEVEL

The self-leveling level (fig. 15-40) is a precise, time-saving leveling instrument and is equipped with a small bull' s-eye level and three leveling screws. The leveling screws, which are on a triangular foot plate, are used to center the bubble of the bull' s-eye level.

The line of sight automatically becomes horizontal and remains horizontal as long as the bubble remains approximately centered. A prismatic

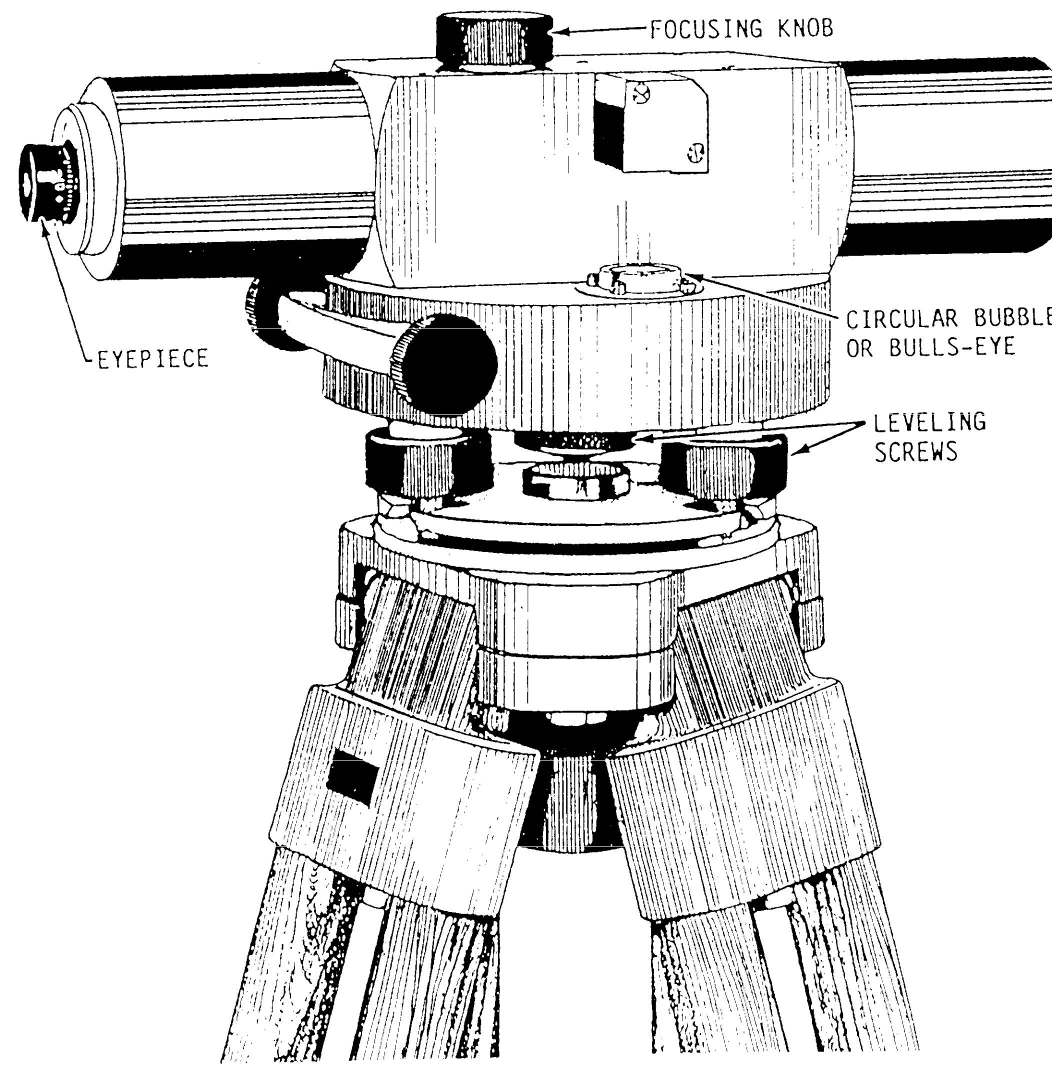


Figure 15-40.—Self-leveling level.

device, called a **compensator** (fig. 15-41), makes this possible. The compensator is suspended on fine, nonmagnetic wires. The action of gravity on the compensator causes the optical system to swing into the position that defines a horizontal line of sight. This horizontal line of sight is maintained despite a slight out-of-level telescope or even a slight disturbance occurs on the instrument.

TRIPOD

The tripod (fig. 15-42) is the base or foundation that supports the level instrument and keeps it stable during observations. A tripod consists of a head to which the instrument is attached, three wooden or metal legs that are hinged at the head, and pointed metal shoes on each leg to be pressed or anchored into the ground to achieve a firm setup.

In setting up the tripod, loosen the restraining strap from around the three legs. An effective way to set the tripod down is to grip it with two of the legs close to your body while you stand over the point where the setup is required. By using one hand, push the third leg out away from your body until it is about 50 to 60 degrees with the horizontal. Lower the tripod until the third leg is on the ground. Place one hand on each of the first two legs, and spread them while taking a short backward step, using the third leg as a pivot point. When the two legs look about as far away from the mark as the third one and all three are equally spaced, lower the two legs and press them into the

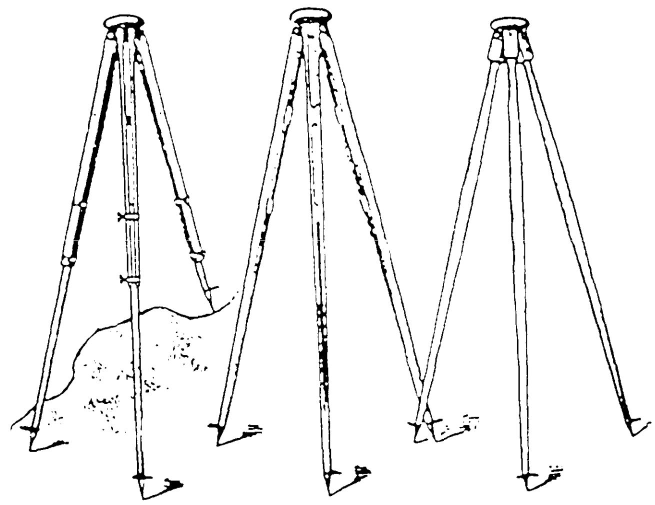


Figure 15-42.—Tripods.

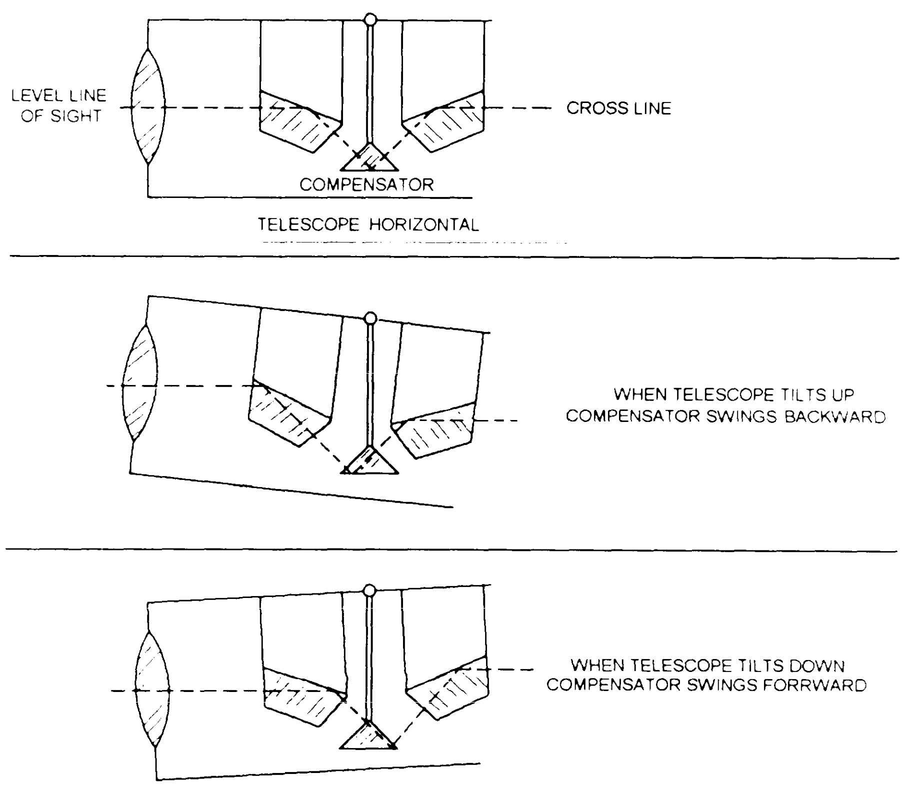


Figure 15-41.—Self-leveling level compensator.

ground. Make any slight adjustments to level the head further by moving the third leg a few inches in or out before pressing it into the ground.

When placing the instrument onto the tripod, grip the instrument firmly to avoid dropping it while you are mounting it on the tripod. The instrument should be screwed down to a firm bearing, but not so tightly that it binds or the screw threads strip.

LEVEL ROD

The most often used level rod is the **Philadelphia rod,** as shown in figure 15-43. It is a graduated wooden rod, made of two sections, and can be extended from 7 feet to 13 feet.

Each foot is subdivided into hundredths of a foot. Instead of each hundredth of a foot being marked with a line or tick, the distance between alternate hundredths is painted black on a white background. Thus the distance between the colors: the top of the black is even values, the bottom of the black is odd values, the tenths are numbered in black, the feet in red.

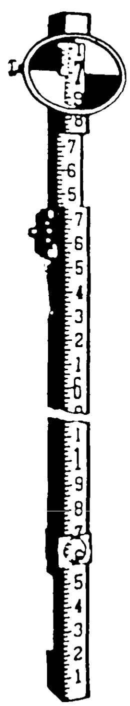


Figure 15-43.—Philadelphia level rod with target.

Direct Reading

Direct readings are taken off a self-reading rod, held plumb on a point by a rodman. If you are working to tenths of a foot, it is relatively simple to read the foot mark below the cross hair and the tenth mark which is closest to the cross hair. But, working to the hundredths of a foot is more complicated. For example, suppose you are making a direct reading which comes out as 5.76 feet. On a Philadelphia rod, the graduation marks are 0.01 foot wide and are 0.01 foot apart. For a reading of 5.76 feet, there are three black graduations between the 5.70-foot mark and the 5.76-foot mark, as shown in figure 15-44. Since there are three graduations, the rod may be misread as 5.73 feet instead of 5.76 feet.

The 5-foot mark or the 6-foot mark does not show in figure 15-44. While sighting through the level instrument, you might not be able to see the foot

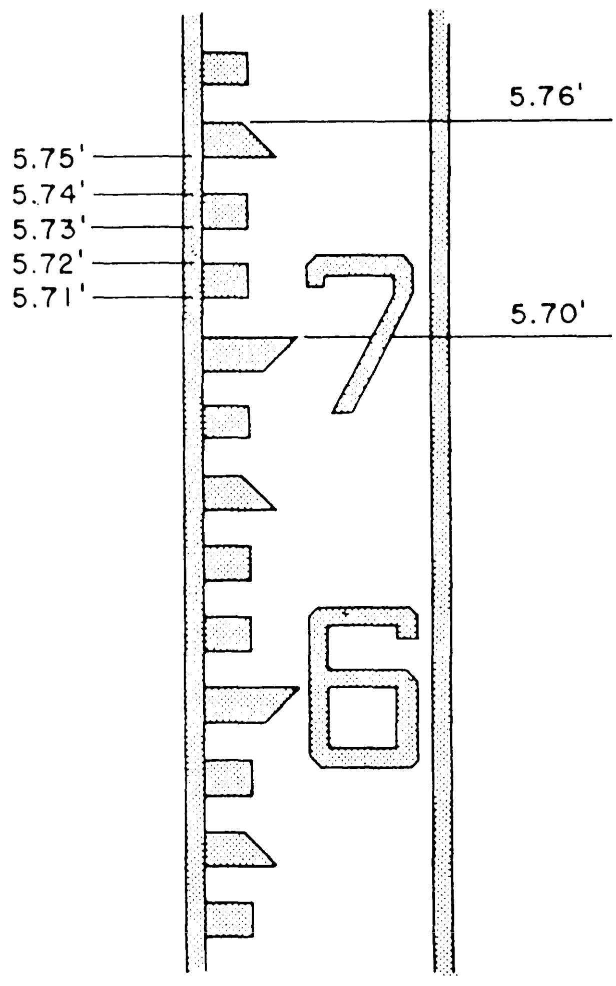


Figure 15-44.—Direct reading of 5.76 feet on a Philadelphia rod.

marks. When you cannot see the next lower foot mark through the level instrument, you signal or ask the rodman to **raise for red.** The rodman should slowly raise the rod until the next lower red number comes into view.

NOTE: The feet measurements on the Philadelphia rod are in red.

Target Reading

Conditions that hinder direct reading, such as poor visibility, long sights, and partially obstructed sights, as through brush or leaves, sometimes make it necessary to use targets. The target is also used to mark a rod reading when numerous points are set to the same elevation from one instrument setup.

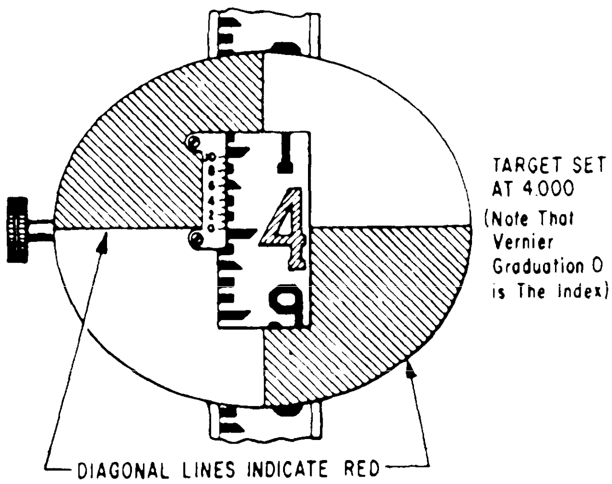


Figure 15-45.—Target.

Targets (fig. 15-45) for the Philadelphia rod are usually oval, with the long axis at right angles to the rod, and the quadrants of the target painted alternately red and white. The target is held in place by a C-clamp and a thumbscrew. A lever on the face of the target is used for fine adjustment of the target to the line of sight of the level. The targets have rectangular openings approximately the width of the rod and 0.15 feet high through which the face of the rod may be seen. A linear vernier scale is mounted on the edge of the opening with the zero on the horizontal line of the target for reading to thousandths of a foot. When the target is used, the rodman takes the rod reading.

When sighting through the level instrument, the levelman motions either up or down so that the rodman can place the horizontal separation of the target in line with the horizontal cross hair of the instrument. When the horizontal separation and the horizontal cross hair coincide, the levelman waves ALL RIGHT.

After the levelman signals the all right, the rodman tightens the target clamp. Then the rodman holds the rod on the point again to ensure the target has not slipped and "waves" the rod by pushing it about a foot away from and towards his body to see if the rod was initially held in an absolutely vertical position. The levelman should recheck the target reading. If the horizontal cross hairs do not coincide, the target must

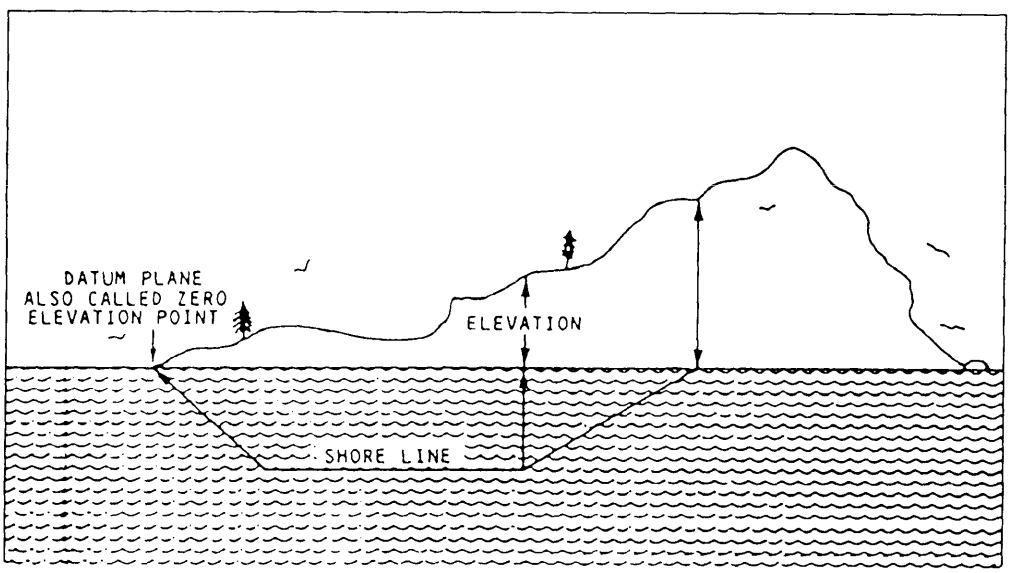


Figure 15-46.—Zero elevation point.

be reset. The rodman reads the target to feet, tenths, and hundredths of the nearest foot gradation below the horizontal quadrant separation line of the target. Equipment Operator's seldom use the vernier scale in earthwork operation.

LEVELING

The vertical distance, measured during leveling, is the **difference of elevation** between two points. The term **elevation** refers to the height of a point or a particular spot above or below a reference line, called a **datum** or **datum plane.**

Datum are of two general types: actual and assumed. An actual datum is **mean sea level** (fig. 15-46). An assumed datum plane is an imaginary level surface assumed to have an elevation of zero. It is used as a convenience in leveling procedures.

A reference point whose elevation is known and marked is called a **bench mark** (B.M.). It is used either as the starting point in leveling or as a point of closure in checking the accuracy of your work.

Bench Marks

Bench marks are classified as **temporary** or **permanent.** Temporaary bench marks (T. B. M.) are established for the use of a particular job and are retained for the duration of that job. Throughout the United States, a series of permanent bench marks has been established by various governmental agencies. These identification markers are set in stone, iron pipe, or concrete and are sometimes marked with the elevation above sea level. Typical markers are shown in figure 15-47.

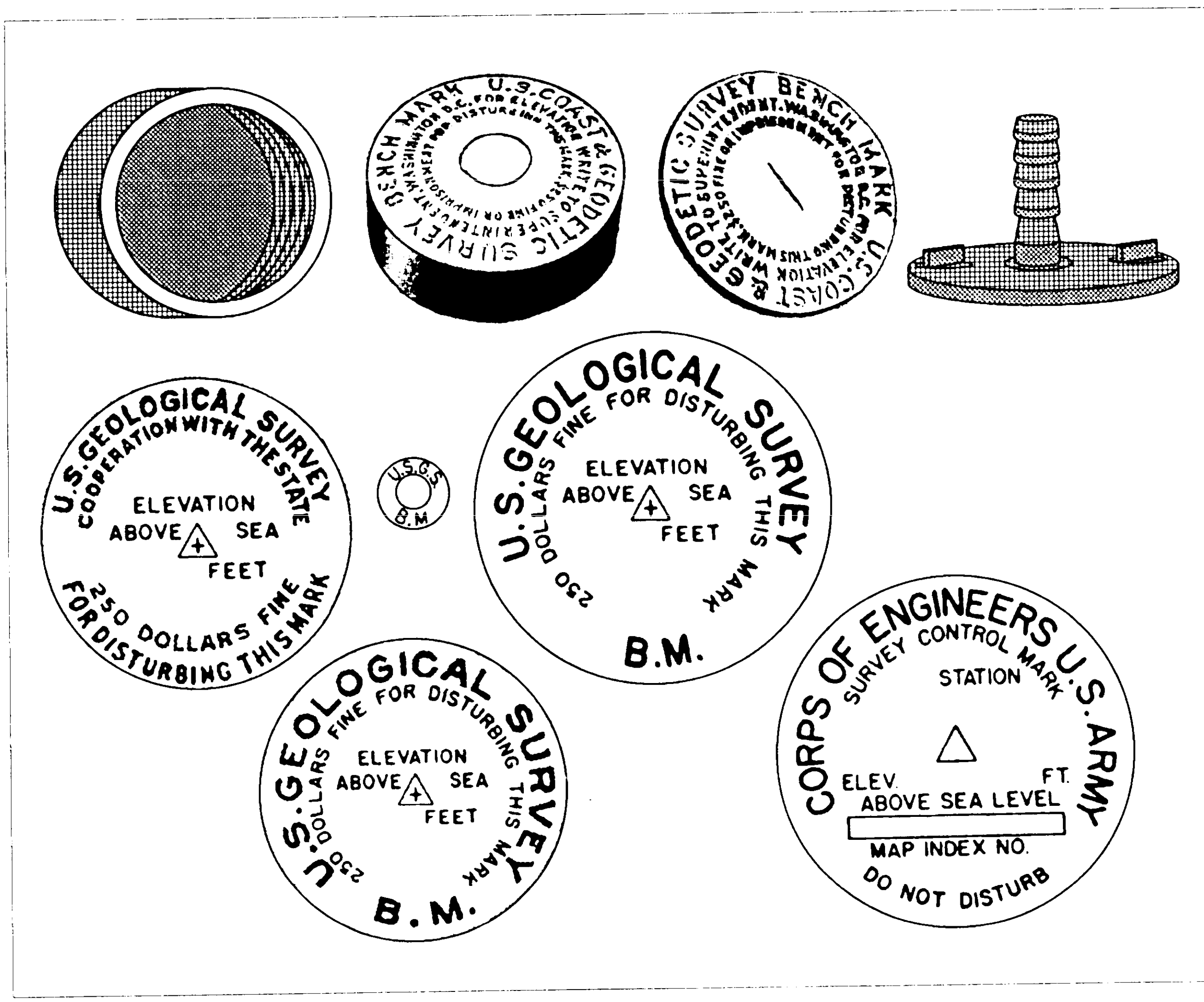


Figure 15-47.—Federal bench marks.

Any substantial object may be used as a bench mark. Figure 15-48, view A, shows typical monuments set to mark important alignment points, but which may also be used as bench marks. Spikes may be driven into posts or power poles, as shown in figure 15-48, view B, or chiseled into stone or concrete structures, as shown in figure 15-48, view C. For clarity, the marks are shown on the wing wall; but in practice, one mark only is usually chiseled or spray-painted on a flat surface.

The location, elevation, and description of bench marks are usually shown on the project drawings or in the surveyor's field notes.

Determining Elevations

Once a bench mark is established, certain formulas are used for determining elevations. You first must figure the height of the instrument. This is done by taking a reading on a level rod that is placed on a known elevation, such as a bench mark. This is known as a **backsight (BS).**

To determine the height (HI) of the instrument, add the bench mark (BM) elevation to the backsight (BS) reading from the level rod. This formula is written as **HI = BM + BS.**

For example, as shown in figure 15-49, the bench mark elevation is 100.00 feet. The backsight reading

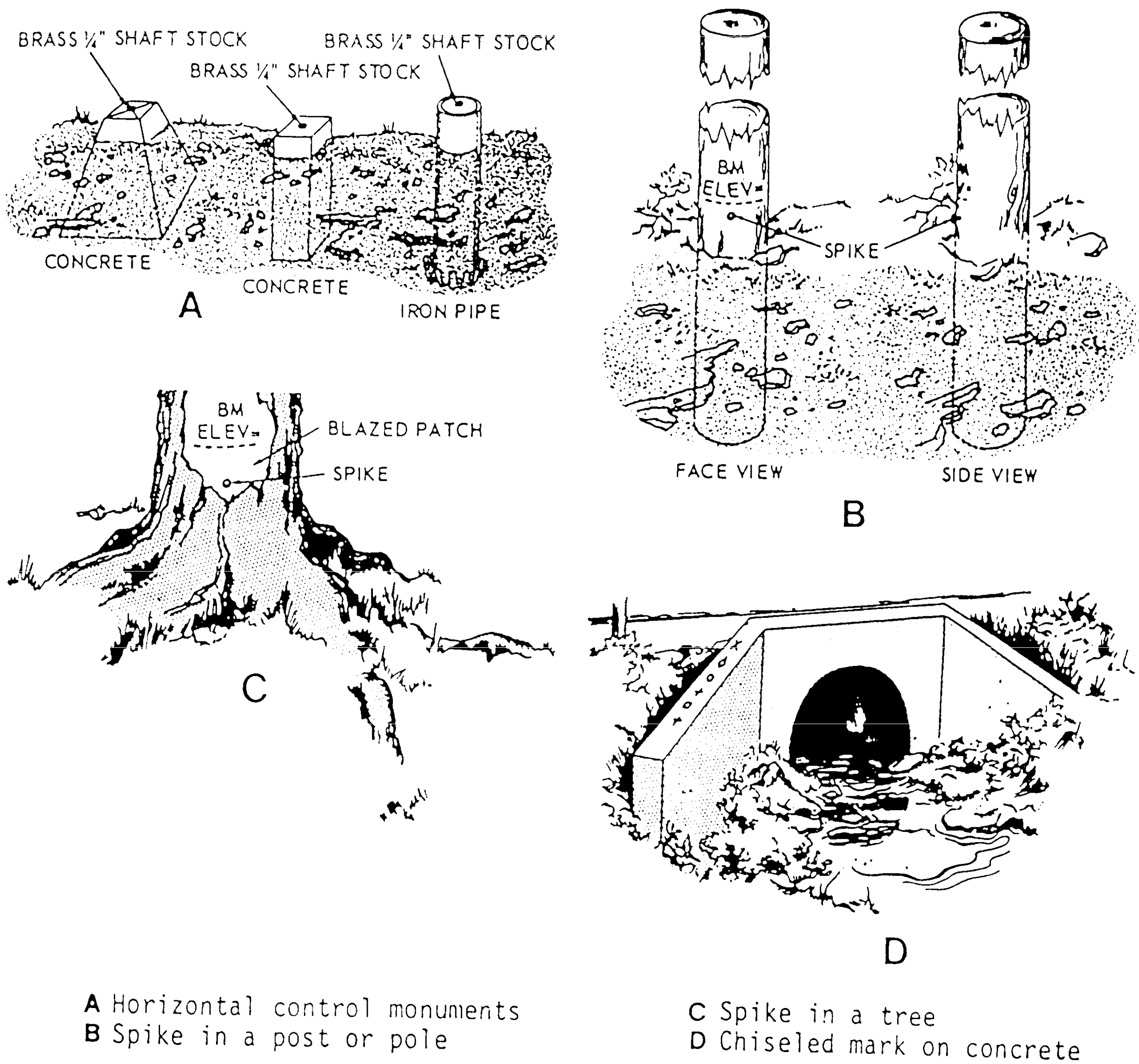


Figure 15-48.—Temporary bench marks.

is 5.5 feet. The bench mark elevation, added to the backsight reading, gives a instrument height of 105.5 feet.

NOTE: Since the backsight (BS) reading is added to the elevation of the bench mark (BM) to obtain the instrument height, it is usually called a plus (+) sight.

Once the height (HI) of the instrument is established, you can determine the elevation of any point within the instrument range.

To determine the elevation of a point after the height (HI) has been established, place the level rod on the point in question and take a reading through the level. This sighting is called the **foresight (FS)** reading and is subtracted from the height to obtain the elevation of the point. The formula for determining elevation is as follows: **HI - FS = EL**

For example, as shown in figure 15-50, the height (HI) of the instrument is 105.5 feet. The foresight (FS) reading is 2.3 feet. The instrument height minus the foresight reading gives that point an elevation of 103.2 feet.

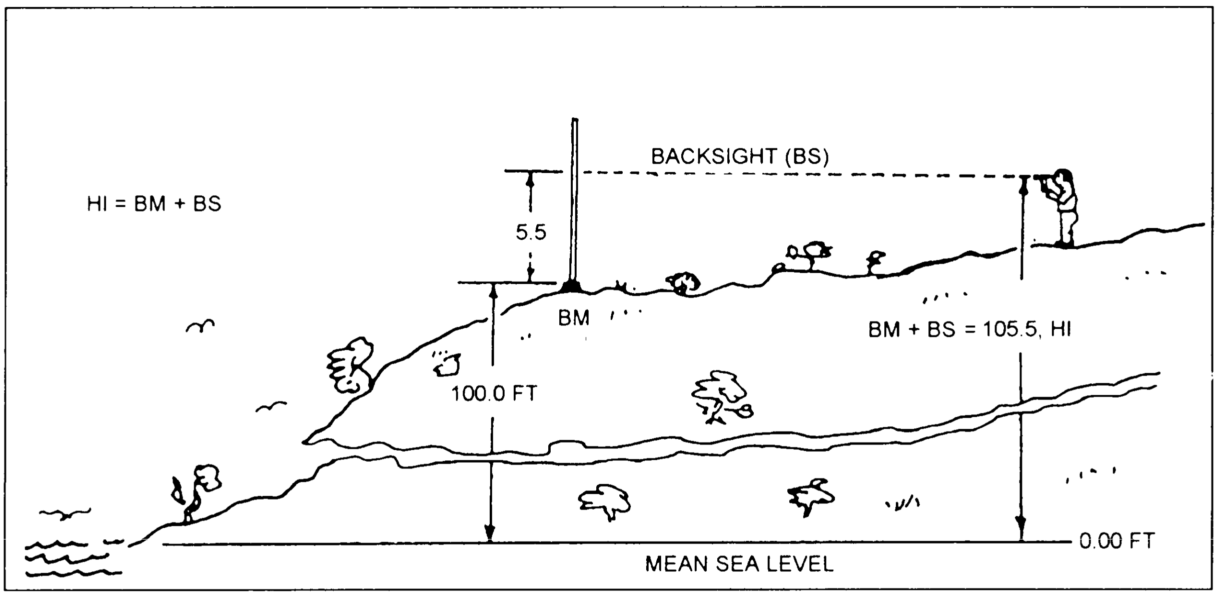


Figure 15-49.—Backsight reading to determine instrument height.

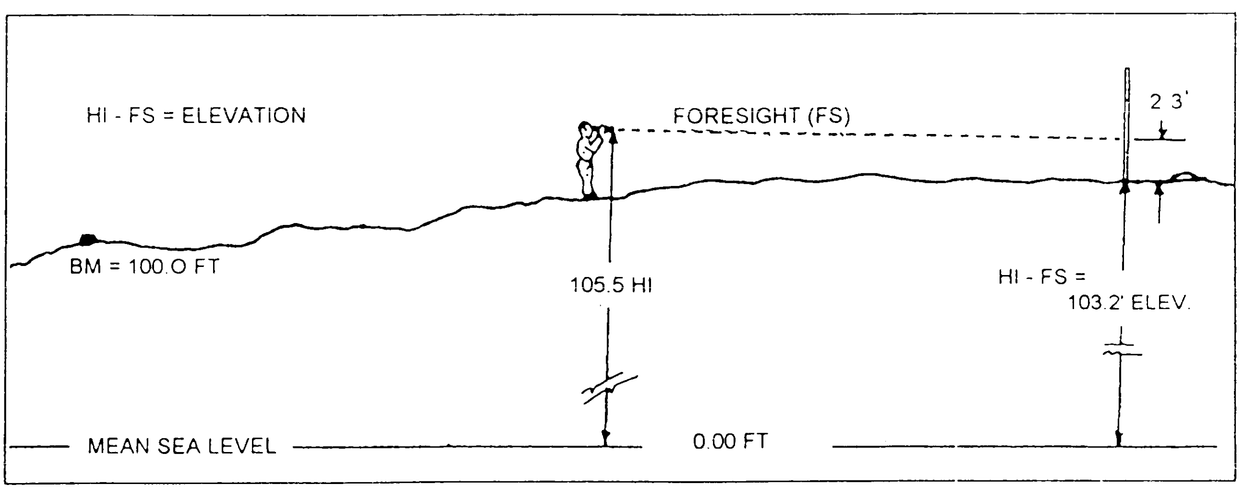


Figure 15-50.—Foresight reading to determine elevation.

Checking Grade with a Level Instrument

An example of checking ground spots for desired grade with a level instrument is shown in figure 15-51.

The hubs and stakes at the side of the construction represent offset grade stakes. In figure 15-51, view (A), the grade stake calls for a cut of 7.5 feet. You set up your level and take two readings: first on the hub and then on the excavation. Your first reading is 5.0 feet. Since the excavation is supposed to be 7.5 feet below the hub, your second reading should be 12.5 (5.0 plus 7.5 as shown). But the rod reads only 12.2; therefore, you must cut 0.3 feet more to get to finished subgrade.

In figure 15-51, view (B), your first reading is 12.0 feet on the hub. Since the stake calls for F 7.0, you should read 5.0 on the completed fill. But the rod reads 5.5; therefore, you must fill another 0.5 feet to finish the subgrade.

MISSING GRADE STAKE.— Another leveling procedure is to compute a cut-or-fill requirement from a missing grade stake. In figure 15-52, the finish elevation from the project drawings at point B is supposed to be 378.75. You setup your level, take a backsight shot on the bench mark at point A, and get a direct reading of 11.56 feet. The 11.56 feet backsight reading plus the bench mark elevation of 365.01 feet gives you an instrument height of 376.57 feet. Then you take a foresight shot at point B, and get a direct reading of 1.42 feet. You now subtract the foresight reading of 1.42 feet from the instrument height of 376.57, and find that the existing ground is at elevation 375.15. You now take the required finish elevation of 378.75 and subtract the existing elevation of 376.15 and get a FILL requirement of 3.6 feet at point B. If the existing elevation is greater than the required finish elevation, you would be required to cut.

Another example of a missing grade stake is shown in figure 15-53. Suppose the stake at station 4 + 50 has been knocked out, and there is no bench mark

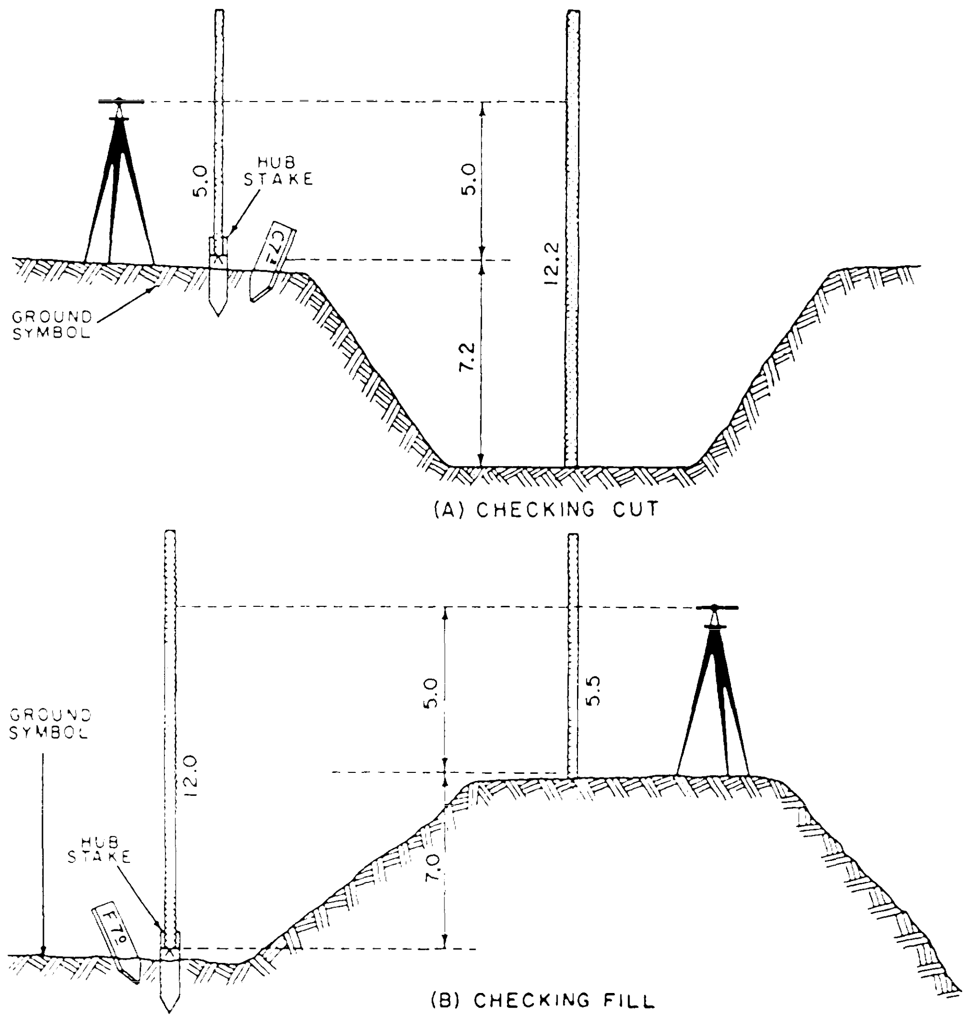


Figure 15-51.—Checking cut and fill.

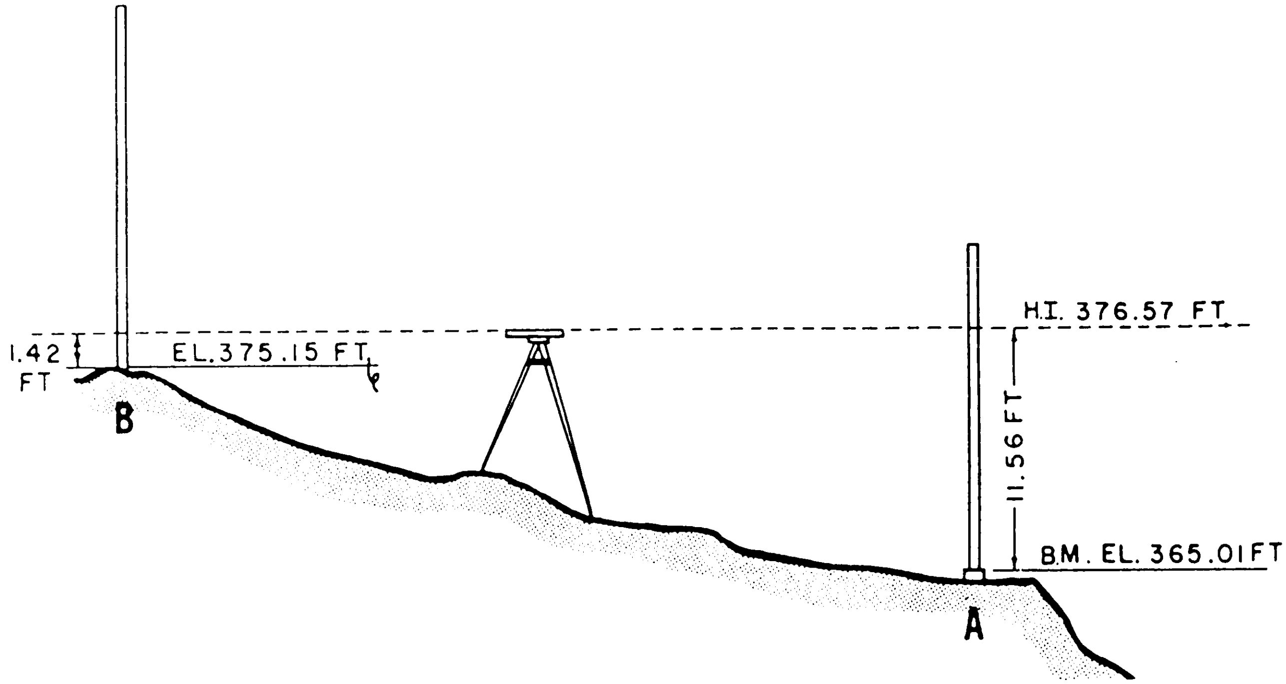


Figure 15-52.—Computing cut-or-fill requirement from a missing grade stake.

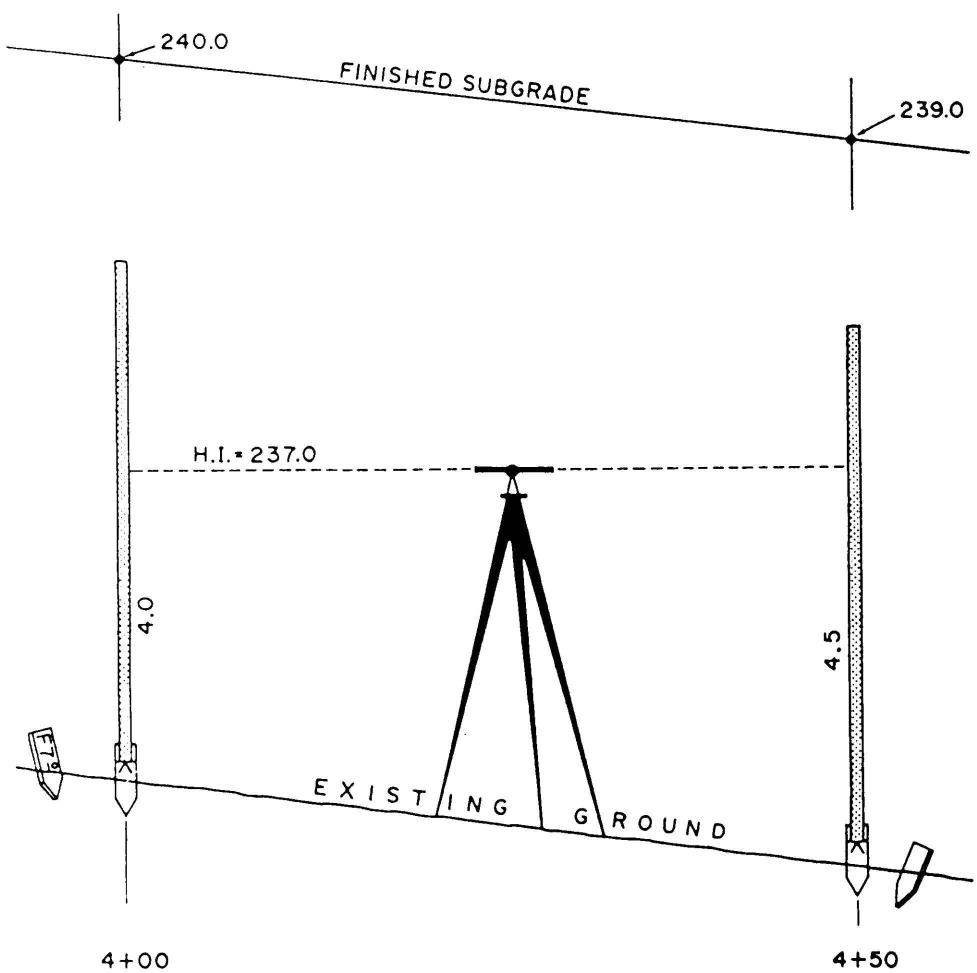


Figure 15-53.—Replacing a missing grade stake.

nearby, but you do have a nearby grade stake at station 4 + 00 and a set of the project drawings.

At station 4 + 00, the project drawings call for a subgrade elevation of 240.0 feet. The stake at station 4 + 00 calls for a fill of 7.0 feet; therefore, the existing elevation at station 4 + 00 is 233.0 (7.0 feet below 240.0).

You set up your level and take a backsight direct reading on station 4 + 00 of 4.0 feet. The backsight reading of 4.0 feet plus the existing known elevation of 233.0 feet gives an instrument height of 237.0. Then you take a foresight shot on station 4 + 50 and get a direct reading of 4.5 feet. You subtract the foresight reading of 4.5 feet from the instrument height of 237.0 feet, and you get at station 4 + 50, the existing elevation of 232.5 feet.

The project drawings show that the finished subgrade elevation at station 4 + 50 is 239.0 feet. With the existing elevation at 232.5, you must FILL at station 4 + 50 a total of 6.5 feet to reach the 239.0 feet required subgrade elevation. Therefore, you should place a grade stake at station 4 + 50 that is marked F 6.5.

TURNING POINT.— The two missing grade stake examples were based on elevations of nearby points that could be read from one setup of the level. If differences of elevation or distance are too great or if there are obstructions, you will have to make an intermediate setup and sight on a point, called a **turning point (T.P.).** Any convenient point may be used as a turning point, but the level rod must be set on firm ground or on some firm object so that the elevation of the T.P. will not change while the rodman waits for the levelman to setup at the new position.

An example of a level run is shown in figure 15-54. You have a B.M. at the bottom of a bank and you want to find the elevation at the top of the bank, which is point A. You cannot set up on the top of the bank to take a reading on the level rod held on point A because to take a backsight shot on the B.M., the level rod is too short.

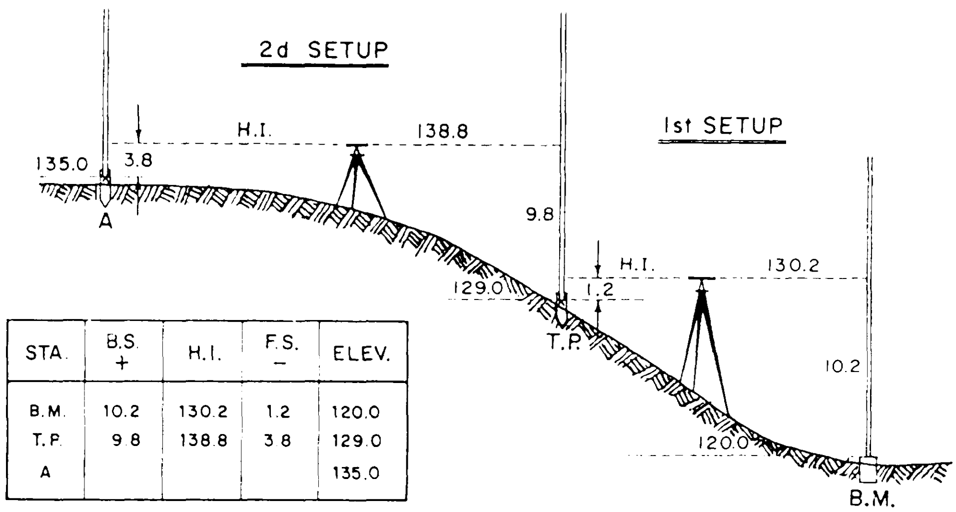
First, record the B.M. elevation of 120.0 feet. Next, set up the level instrument on the bank and take a backsight shot on the B.M. to get a level rod reading of 10.2 feet. Add the backsight shot of 10.2 feet to the B.M. elevation of 120.0 feet to get the first instrument height of 130.2 feet. Then take a foresight shot on the T.P. to get a level rod reading of 1.2 feet. Subtract the 1.2 feet foresight reading from the 130.2 feet instrument height to get a T. P. elevation of 129.0 feet.

Next, move the instrument to the top of the bank. Take a backsight shot on the T.P. to get a level rod reading of 9.8 feet. Add the 9.8 feet backsight reading to the 129.0 feet T.P. elevation to get a second instrument height of 138.8 feet. The last step is to take a foresight shot on point A to get a level rod reading of 3.8 feet. Subtract the 3.8 feet foresight reading from the 138.8 feet second instrument height to get a 135.0 feet point A elevation.

Some level runs may require more than one T. P.; however, no matter how extensive the job, the procedure is always the same: you add and subtract successive rod readings from a point of known elevation to the point of unknown elevation.

MEASURING HORIZONTAL DISTANCES

Setting or replacing grade stakes requires measuring horizontal distances with either a **woven tape** or a **steel tape.**



STA.	B.S. +	H.I.	F.S. −	ELEV.
B.M.	10.2	130.2	1.2	120.0
T.P.	9.8	138.8	3.8	129.0
A				135.0

Figure 15-54.—Turning point and level notes.

A woven tape (fig. 15-55) is made of high-grade cloth (usually linen) fabric. A metallic, woven tape is reinforced with fine bronze or brass wire mesh. A nonmetallic, woven tape does not contain the mesh; however, some nonmetallic, woven tapes are coated with plastic.

Woven tapes are made in 25-, 50-, 75-, 100-, and 150-foot lengths. Some are graduated in feet and inches to the nearest quarter inch. Others are graduated in feet and decimals of a foot to the nearest 0.05 foot. On most decimally graduated woven tapes, only the 0.10-foot graduations are marked with numerals.

The steel tape is used for measurements requiring greater precision than is possible with the woven tape. The most commonly used steel tape is 100 feet in length and is graduated in feet, tenths, and hundredths. Some steel tapes are graduated throughout; on others, only the first foot is graduated in subdivisions and the body of the tape is graduated only at every 1-foot mark. A steel tape is sometimes equipped with a reel on which the tape can be wound. The tape can be detached from the reel for more convenient use in taping.

For convenience in carrying from one place to another, a detached tape can be made up into a coil, commonly called "DOING UP' the tape. This is done by placing the 100-foot end (or the 200-foot, 300-foot, etc., end) in your left hand, faceup; then reach back with your right hand, grasp the 95-foot mark, bring it up, and place it faceup on top of the 100-foot mark. Do the same with the 90-foot mark, the 85-foot mark, the 70-foot mark, and so forth, until you have gathered in the entire tape. You will find that the tape now forms a figure-of-eight, as shown in figure 15-56. The figure-of-eight can be formed into a circular coil, as shown in figure 15-57.

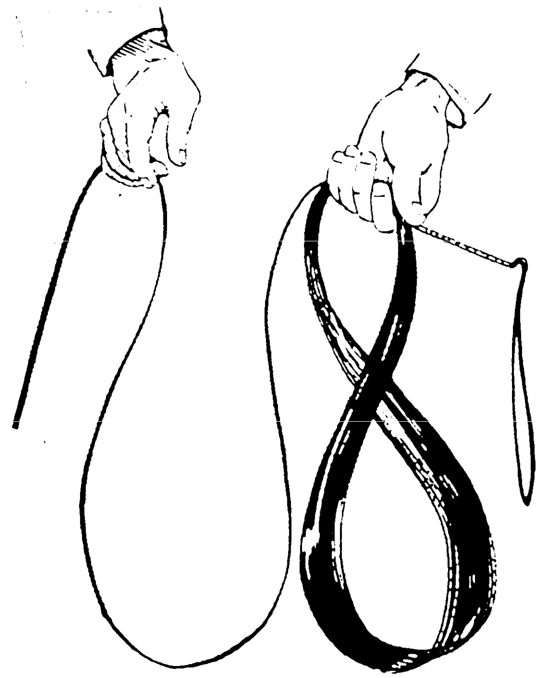


Figure 15-56.—Doing up a steel tape.

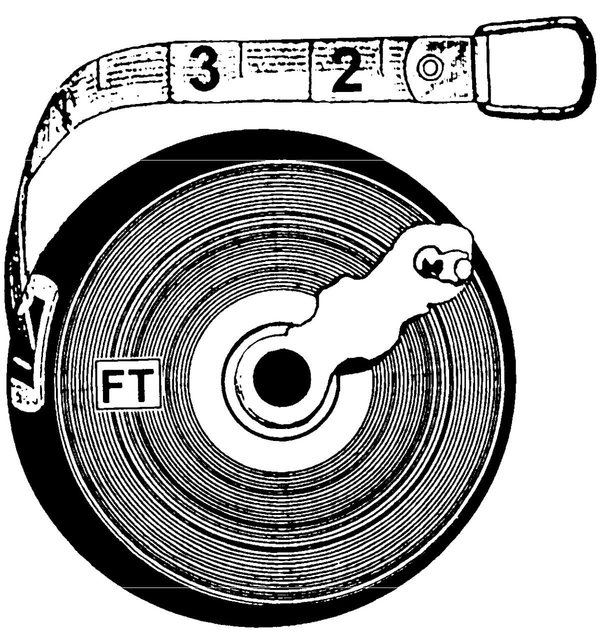


Figure 15-55.—Woven tape.

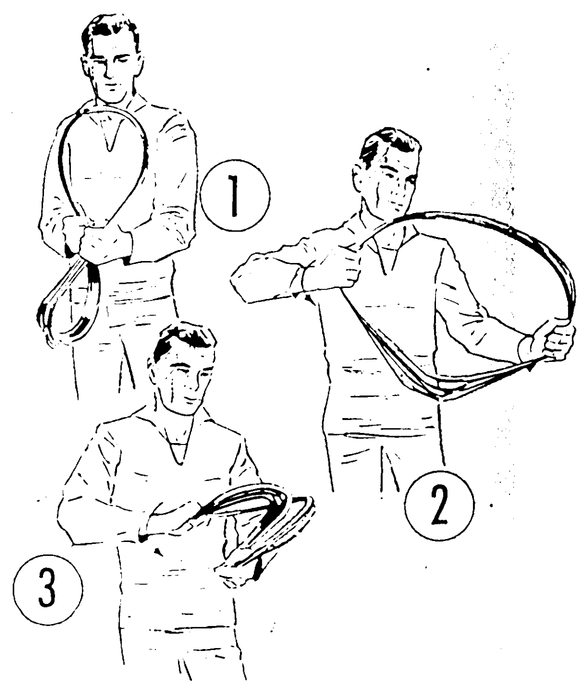


Figure 15-57.—Steps in throwing a steel tape into a coil.

ERRORS AND MISTAKES

Some of the common errors and mistakes made in leveling are as follows:

- Inaccurate adjustment of the instrument: The most common instrument error is caused by a level out of adjustment. The instrument must be adjusted, so the line of sight is horizontal when the bubble is in the center of the tube.

- Errors in sighting: If the eyepiece of the telescope is not properly focused, the rod reading appears to change, because the position of the eye is changed with respect to the eyepiece.

- Errors due to changes in the position of the instrument: When the instrument is not properly leveled or if it is set up in an unstable position, errors due to settlement will result. An unstable instrument setup makes the level bubble tremble slightly, even though it appears to be properly centered. Check the position of the bubble before and after each rod reading to make sure that the bubble has remained in the center of the tube.

- Faulty handling of the rod: The rod may not be properly plumbed. If the rod is not held plumb, such as if it leans toward or away from the instrument, the result will be an excessive reading.

- Erroneous rod length: Check the length of the extended leveling rod with a steel tape.

- Failure to clamp the rod at the proper place when an extended leveling rod is used: This error could result in reading the wrong mark on the rod or reading the wrong cross hairs. Inspect the clamped positions before and after each sight to make sure that the extended rod has not slipped down.

SOILS

The soil is an important part of a solid foundation. A poor foundation will eventually cause roads, runways, buildings, and other temporary or permanent structures to collapse.

SOIL FORMATION

Soils are formed through the breakdown of a solid rock mass or parent material into smaller particles, You may have seen rocks that have been crumbled up or that were softer than others. This is one step in the breakdown of rock into soil. Rocks wear away when they are in contact with moving water, as seen in stream beds or rivers. Rocks also break up when they freeze and thaw. When rocks heat up by the sun and then cool quickly, they crack.

Soil Profile

During formation, soils are in a natural profile made up of three distinct layers (fig. 15-58).

The upper layer, A-horizon, is made up mostly of organic materials. Because these materials are spongy, drain poorly, and do not compact, they are normally removed before building anything on this layer.

The B-horizon lies directly beneath the view A-horizon. This layer is lighter in color and is made up of sand, gravel, silt, and clay. Seldom is soil in its natural state made up of only sand, gravel, silt, or clay. Most soil is made up of a mixture of the four. How strong and free-draining the soil is depends on the type and amount of each in the mixture. The B-horizon is usually the base for all types of pavement construction.

The C-horizon is rock in its natural state. It is sometimes called **parent** material, because this is where B-horizon material comes from. Very seldom are projects built on the C-horizon.

Soil Properties

With experience, you will learn that you can use different properties of soil to your advantage. Soil properties are as follows:

- Expansion
- Contraction
- Plasticity
- Cohesion

Expansion and contraction are undesirable characteristics for a solid foundation that must be monitored closely. Clays and some forms of silt expand and contract with changes in moisture content. Plasticity is the ability of a soil to be molded into shapes. Some clays and silts are also plastic and can be a problem if not controlled properly. Cohesion is the ability of soil to stick together when dry, and a good example are clays which are very cohesive. The more plastic a soil is when wet, the more cohesive it is when dry.

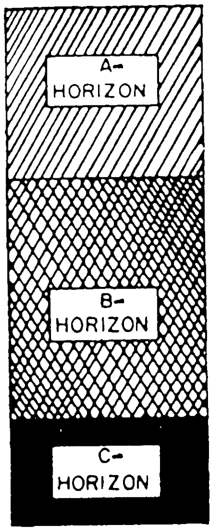


Figure 15-58.—Soil profile.

Soil Classification

The soils you normally work with in earthwork operations are classified as follows:

- Coarse grained
- Fine grained
- Organic

COARSE-GRAINED SOILS.— Soils in this classification are composed of sand and gravel and are in the B-horizon. Coarse-grained soils have 50 percent or less material passing the No. 200 sieve. Their grain shape varies from rounded to angular and has good load-bearing qualities and drains freely.

FINE-GRAINED SOILS.— Fine-grained soils are composed of silt and clay and are in the B-horizon. They have 50 percent or more material passing the No. 200 sieve. Fine-grained soils have good-load bearing qualities when dry; however, these soils drain poorly, and when wet, have little or no load-bearing strength. This characteristic is especially true with clay.

ORGANIC SOILS.— Organic soils, sometimes referred as **top soil,** are composed mostly of decayed plant and animal matter and are in the A-horizon. These soils retain moisture, are difficult to compact, and are normally used when landscaping a finish project.

Soil Sizes

Soils are grouped by the size of their particle grains. One method used to distinguish sizes is through the use of sieves (fig. 15-59). A sieve is a screen attached across the end of a cylindrical metal frame. The screen allows particles smaller than its openings to fall through and retains larger particles. Sieves with screen openings of different sizes allows you to sort soil into particle groups, based on size.

Sieve sizes are designated by the screen opening size; for example, a 3-inch sieve has a screen with openings 3 inches square. A No. 4 sieve has four openings per linear inch, thus having 16 openings per square inch.

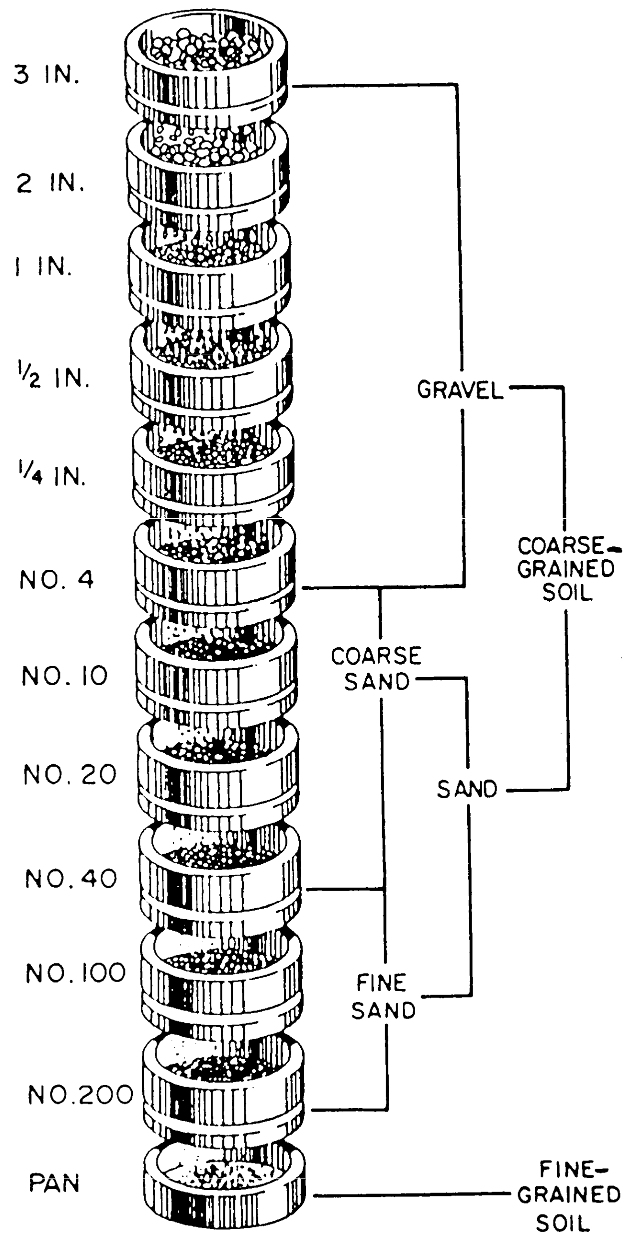


Figure 15-59.—Standard sieve set.

If a soil sample passes the 3-inch sieve but does not pass the No. 4 sieve, the larger particle size is less than 3 inches and the smallest size is larger than 1/16 inch. This soil is classified as gravel.

Soils that pass the No. 4 sieve but are retained on the No. 200 sieve are classified as sands. Sands are further broken down as coarse sand or fine sands. Coarse sand passes the No. 4 sieve and is retained on the No. 40 sieve. Fine sand passes the No. 40 sieve and is retained on the No. 200 sieve.

Any soil, passing the No. 200 sieve, is classified as fine-grained.

Soil Gradation

Gradation describes the distribution of different size groups within a soil sample. A **well-graded soil** (fig. 15-60) is a soil sample that has all sizes of material present from the No. 4 sieve to the No. 200 sieve.

Poorly graded soil may be **uniformed-graded** (fig. 15-61) or **gap-graded** (fig. 15-62). If a soil is uniformed-graded, most of its particles are about the same size. An example of this is a sieve analysis in which sand size No. 20 is the only size present.

If a soil is gap-graded, at least one particle size is missing. An example of gap-graded soil is one in which a sieve analysis reveals that sand sizes No. 10 and No. 40 are missing. All other sizes are present.

Soil Compaction

Compaction is pressing together soil particles to form a consolidated mass with increased stability.

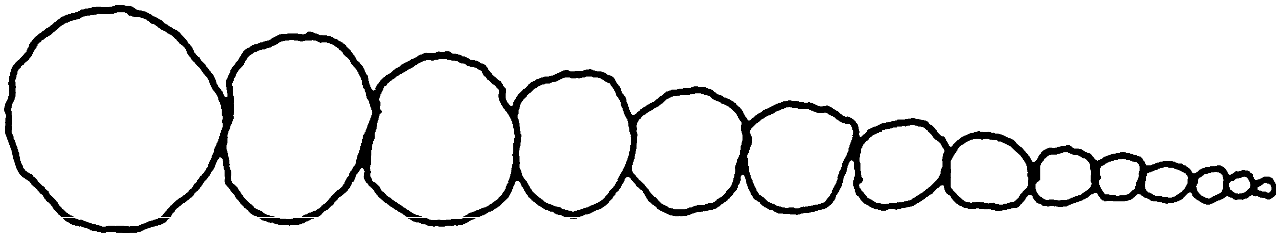


Figure 15-60.—Well-graded soil.

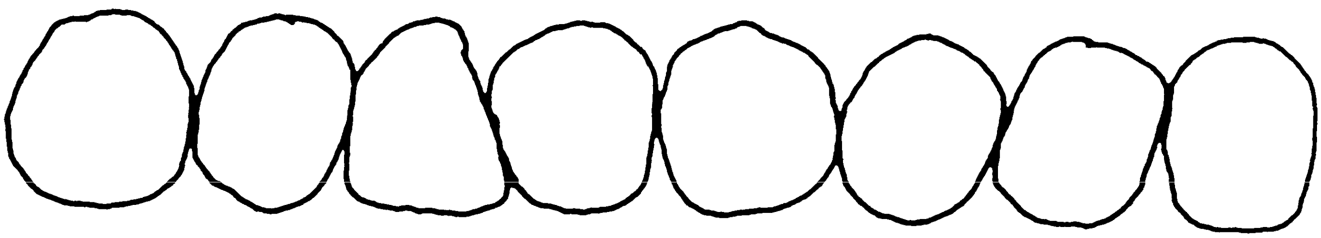


Figure 15-61.—Uniform-graded soil.

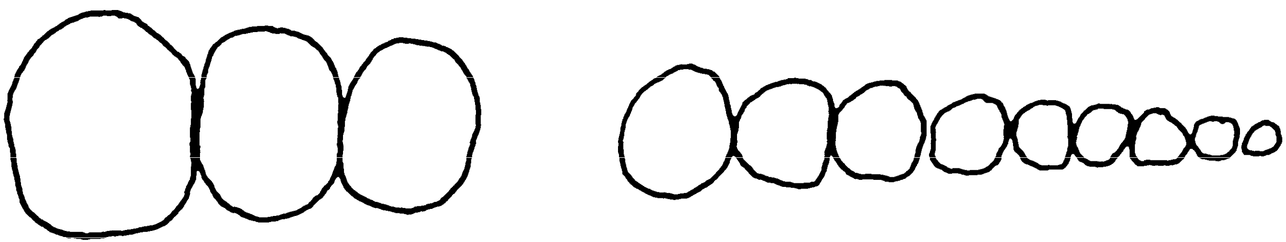


Figure 15-62.—Gap-graded soil.

Compaction helps the soil to be more resistant to soaking up moisture from below.

Fills are built up in compacted layers. In earthwork operations, these layers are called **lifts.** Lifts are from 4 inches to 1 foot in depth, depending upon the compaction necessary, compaction equipment available, and material used for the fill.

The fill material must have the right amount of moisture, referred to as **optimum moisture content.** To obtain maximum compaction, wet the fill, when necessary, before it is compacted. Compaction may be obtained by using a pneumatic, tandem, or vibratory roller.

SOIL STABILIZATION

There are three purposes for soil stabilization. The first one is strength improvement. This increases the strength of the existing soil to enhance its load-bearing capacity. The second purpose is for dust control. This is done to eliminate or alleviate dust, generated by the operation of equipment and aircraft during dry weather or in arid climates. The third purpose is soil waterproofing, which is done to preserve the natural or constructed strength of a soil by preventing the entry of surface water.

There are two methods used to apply soil stabilization materials. The first is the admix way. This is used where it is necessary to combine two different soils together for stabilization. This can be done as follows:

- In-place mixing: accomplished by blending of soil and stabilization materials on the jobsite.

- Off-site mixing: accomplished by using stationary mixing plants.

- Windrow mixing: accomplished by mixing the materials using a grader.

The second way is the surface penetration application, which is accomplished by placing a soil treatment material directly to the existing ground surface by spraying or other means of distribution. Some of the additives used in soil stabilization are cement, lime, bituminous products, and calcium chloride. Cement-treated bases are the most commonly used for the purpose of upgrading a poor quality soil. Soil-cement is a mixture of pulverized soil and measured amounts of portland cement and water, compacted to a high density.

There are three types of soil-cement. The first type is compacted soil-cement that contains sufficient amounts of cement to harden the soil and enough moisture for both compaction and hydration of the cement. The second type is cement modified soil which is an unhardened or semihardened mixture of soil and cement. Only enough cement is used to change the physical properties of the soil. The third is plastic soil-cement. It is a hardened mixture of soil and cement that contains at the time of placing, enough water to produce a consistency similar to that of plastering mortar. The three basic materials needed when working with soil-cement are soil, portland cement, and water. The soil can almost be any combination of gravel, sand, silt, or clay.

Three major control factors when working with soil-cement are as follows:

1. The proper cement content is needed. A rule of thumb: use one 50-pound bag per square yard.

2. Proper moisture content. On a soil sample, a firm cast should be made when squeezed in your hand without squeezing out any water.

3. Adequate compaction. The principles of compacting soil-cement are the same for compacting the same soils without cement treatment. The soil-cement mixture at optimum moisture content should be compacted to maximum density and finished immediately. Moisture loss by evaporation during compaction, as indicated by the graying of the surface, should be replaced with light applications of water.

Occasionally during compaction, the treated area may yield under the compaction equipment. This may be due to one or more of the following causes: (1) the soil-cement mix is much wetter than optimum moisture content, (2) the soil may be too wet and unstable, and (3) the roller may be too heavy for the soil. If the soil-cement mix is too damp, it should be aerated by using the scarifier on the grader. After it has dried to near optimum moisture content, then it is compacted.

TECHNIQUES OF EARTHWORK OPERATIONS

Techniques of earthwork operations consist of knowing the equipment needed and the operations of pioneering, clearing, grubbing, stripping, draining, and grading and excavating. These operations are done primarily with heavy construction equipment, such as bulldozers and graders. Hand- or power-felling equipment, explosives, and fire are used when they make the completion of these operations easier.

CAUTION

Large-scale clearing and grubbing operations often produce damaging environmental effects, such as increased soil erosion, reduction of atmospheric oxygen, and destruction of wildlife habitat. Additionally, introduction of particulate matter into streams and riverbeds causes increased siltation and algae growth. Federal regulations may require an environmental impact statement or assessment prior to beginning clearing operations.

To prevent these damaging effects, save as much vegetation as possible, such as trees, grass, and other plants, to hold the soil in place. Constructing a shallow trench or application of plastic barriers or hay bales around the perimeter of a project will help to contain water runoff into streams and rivers, preventing siltation. Burning of scrubs and stumps should be done only when atmospheric conditions are favorable and the material to be burned is dry, However, **do NOT** use petroleum base fuels to start fires, as fuels do not burn completely and seep into the underground water table.

NOTE: A burn permit is required in all burning operations on NCF projects to prevent wild fires and production of smog.

When determining the methods of earthwork operations needed, consider the following factors:

- The acreage to be cleared
- The type and density of vegetation
- The physical features of the land
- The expected weather conditions
- The time available for completion of the job

For best results, a combination of methods should be used in a sequence of operations. Use the method most suitable and effective for the job.

EQUIPMENT

Knowing your equipment, its limitations, and its operating characteristics is part of the knowledge you need to know to be an efficient EO on earthmoving jobs.

Equipment production must be determined so that the correct amount and type of equipment is selected for a project. Equipment production rates are available in the *Seabee Planner's and Estimator's Handbook*, NAVFACP-405. The handbook provides information on estimating construction work elements and material quantities, including equipment and manpower requirements.

Before you begin earthmoving operations, it is often necessary to remove overgrowth, boulders, and other obstructions. Also, you often have to build a drainage system, so the construction site will drain. These operations are carried out with bulldozers, scrapers, graders, and similar equipment.

The load, hauled by a scraper, is usually referred to as either **heaped** or **struck** (fig. 15-63). When moving earth, take a full, heaped load and make it

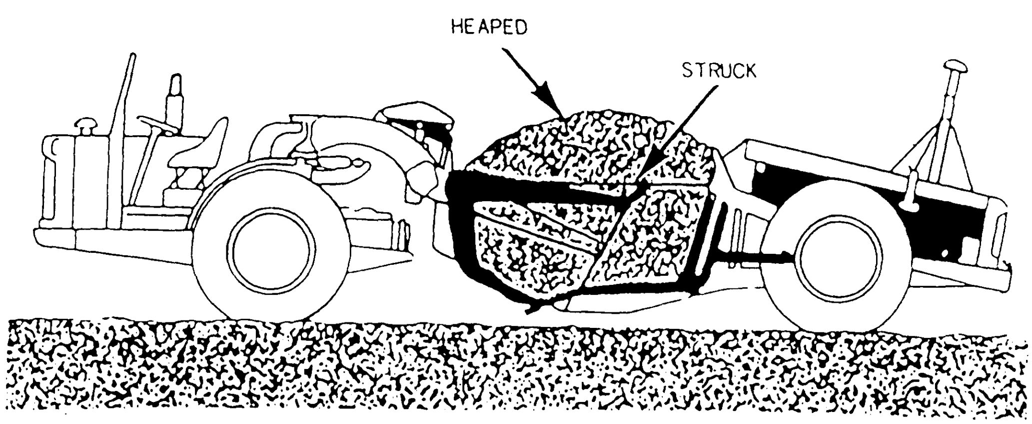


Figure 15-63.-Heaped and struck load.

count. In earthmoving operations, travel can be time-consuming. Suppose you are operating a 12-cubic-yard scraper. It will carry about a 15-cubic-yard heaped load. If you carry only a struck (level) load of 12 cubic yards, you lose 3 cubic yards of load each trip. To move 60 cubic yards takes five trips when only 12 cubic yards are hauled each time. Hauling full, heaped loads, you would move the same amount of material in four trips. If your haul is short and units are waiting to go into the cut, you can increase production by taking only a good load (somewhere between struck and heaped) and moving out, rather than spending extra time obtaining a heaped load.

On most construction jobs, both cuts and fills are required. To increase job efficiency, plan your job so that the material taken from a cut is used in a fill area. This is known as **balancing the material.**

PIONEERING

Pioneering refers to the first working over of an area that is overgrown or rough and making that area accessible for the equipment needed for the project.

In pioneering, the operations of clearing, stripping, grading, and drainage are all done practically at the same time, rather than performed as separate operations. A dozer starts out along a predetermined route and leaves a road behind it. This may be a haul road on which trucks and equipment will use in later operations.

Suppose you, as a dozer operator, get the job of cutting a road on the side of a mountain to be used for access to a proposed airstrip or to reach a mountain stream to be developed into a water supply system. Where should you start and how should you proceed? The route your mountain road is to follow will be staked out by a survey party. You should start your road at the highest point possible and let the force of gravity help the dozer.

In clearing on sidehill cuts, brush and trees should be cast far enough to the side of the road so that they will not be covered with the earth. It is even better if you can cast them over the edge with an angle blade of the dozer when the road is cut. When cutting the road, do not watch the grade stake immediately ahead or you will find yourself below grade. Instead, watch the third or fourth stake down.

NOTE: It is better to be above grade and come back and cut down to grade than to be below grade and have to come back and fill.

CLEARING

Clearing is a construction operation consisting of cleaning a designated area of trees, timber, brush, other vegetation, and rubbish; removing surface boulders and other material embedded in the ground; and disposing of all material cleared.

Clearing, grubbing, and stripping are different in every climatic zone, because each has different types of forests and vegetation. The nature of a forest can be determined from records of the principal climatic factors, including precipitation, humidity, temperature, sunlight, and the direction of prevailing winds. The types of forests can be generally classified as temperate, rain, monsoon, or dry, according to the climates in which they exist.

Clearing usually consists of pushing uprooted trees, stumps, and brush in both directions from the center of the area to be cleared. Clearing should be accomplished so that debris (spoil material) is placed in a designated spot with only one handling. In clearing landing strips, for example, it is generally necessary to dispose of material along each side of the strip outside the construction site. If the site permits burning, the haul distance can be reduced by piling brush, stumps, and trees on the site and burning them. Production in this field must be estimated, rather than calculated.

GRUBBING

Grubbing consists of uprooting and removing roots and stumps. In grubbing, stumps that are difficult or impossible to pull out, even with winches, should be burned or blasted. Your supervisor will decide the method. If the stumps are to be removed by blasting, a qualified blaster must be called upon to do the job. If they are to be burned, you may be assigned the task. Green stumps require continuous application of heat before they catch fire. Check with your supervisor about safety measures that should keep the fire from getting out of control if you have to do any stump burning. Remember that it may take as long as 3 or 4 days for a stump to burn out. Keep a check on the burning during this period. If a project has a high priority and time must be saved, stumps will probably be blasted, rather than burned. When stumps have been removed, refill the holes and level the area to prevent the accumulation of water.

STRIPPING

Stripping consists of removing and disposing of objectionable topsoil and sod. It may either follow or be done with clearing and grubbing. Actual earthmoving begins with stripping; surface soil and rocks are removed from the area to be excavated. Deeply embedded rocks and large boulders may have to be blasted before they can be removed.

The material removed by stripping is called **spoil.** Unless otherwise directed, you should dump spoil along the area to be excavated within range of the earthmoving equipment. If the spoil will not be put to use, such as turfing or finishing the shoulder of a road or runway, it should be wasted along the edges of the project, as shown in figure 15-64. Take care not to disturb necessary drainage.

Equipment, commonly used in stripping, consists of a dozer, a scraper, and a grader. As mentioned earlier, the dozer is the most often used when removing trees. Dozers can handle all short-haul excavations (up to 300 feet). For long-haul excavations (over 300 feet), scrapers should be used. A scraper may be used also on fine soils for shallow stripping. A grader is used mainly for shaping and finishing a stripped surface. It is adaptable also for ditching, for sidecasting, and for sloping banks.

DRAINAGE

Drainage is the construction of facilities needed to allow excess surface and subsurface water to flow from the construction site. Properly designed and constructed drainage systems are one of the most important parts of a construction project. Without proper drainage, rainwater and water running off the surrounding ground could turn the area into a lake. It is also necessary to drain off surface water that would soak down and wet the subgrade.

The elements, determining drainage needs for a road or project site, are the amount of annual rainfall in the area and the routes or areas that can be used to collect or channel excess surface and subsurface water, such as lakes, ponds, streams, or voids (i.e., gullies).

The type of soil is critical to the design and construction of a road. It is poor judgment to construct a road over or through clay, sand, or other undesirable material if it cannot be properly compacted. It is best to bypass this type of material.

If a road surface is to endure continued use for years, it must have firm support from the subgrade. All organic materials, such as living or decayed vegetation, should be removed from the area of the subgrade unless the road is for emergencies or is temporary (detour or military road). In designing and building a road, consider the type of drainage, the type of soil, and the amount of clearing or grubbing necessary.

To facilitate drainage, excavate diversion ditches to conduct all surface water into natural channels or outfall ditches. **Outfall ditches** are constructed to drain low or boggy spots. At the point or the end of the system when the accumulated runoff discharges into the disposal point, the runoff is technically known as **discharge.** The discharge point in the system is called the **outfall.** This preliminary work is done at the same time the area is cleared and grubbed.

The finished drainage system usually consists of ground slopes, ditches, culverts, gutters, storm drains, and underground water drains. Open channels should

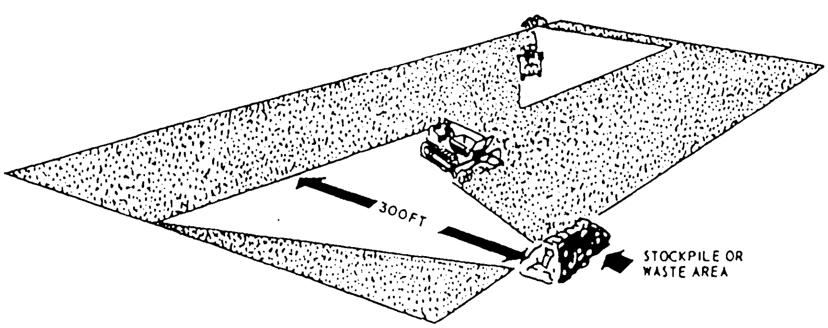


Figure15-64.-Stripping.

be used to intercept or control surface water. These should be dug by bulldozers, scrapers, backhoes, or motor graders, depending on circumstances. Culverts are constructed to drain water across a construction site. Subdrains to drain groundwater are usually excavated with ditchers or backhoes. The drains used are **french drains** (perforated or open-joint tile pipes). Figure 15-65 shows typical covered and french drains.

Runoff water from rain or melted snow is removed from the area by constructing an adequate transverse slope or crown. This runoff is collected in ditches and drained into the nearest natural drainage channel. Drainage for construction sites can be provided by building the ends of the site sloping towards the middle or sloping from one end to the other. These types of drainage construction are shown on the runways in figure 15-66.

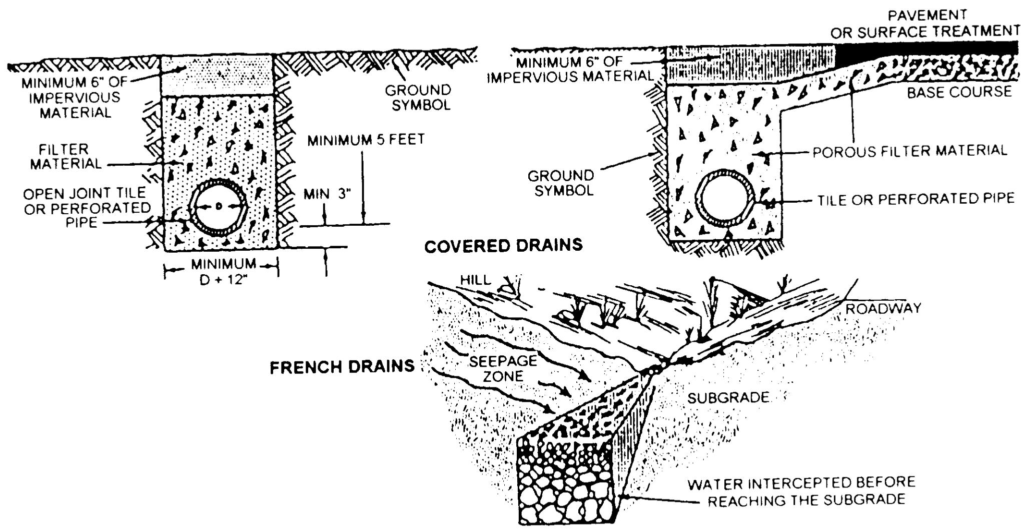


Figure 15-65.—Typical sections of covered and french drains.

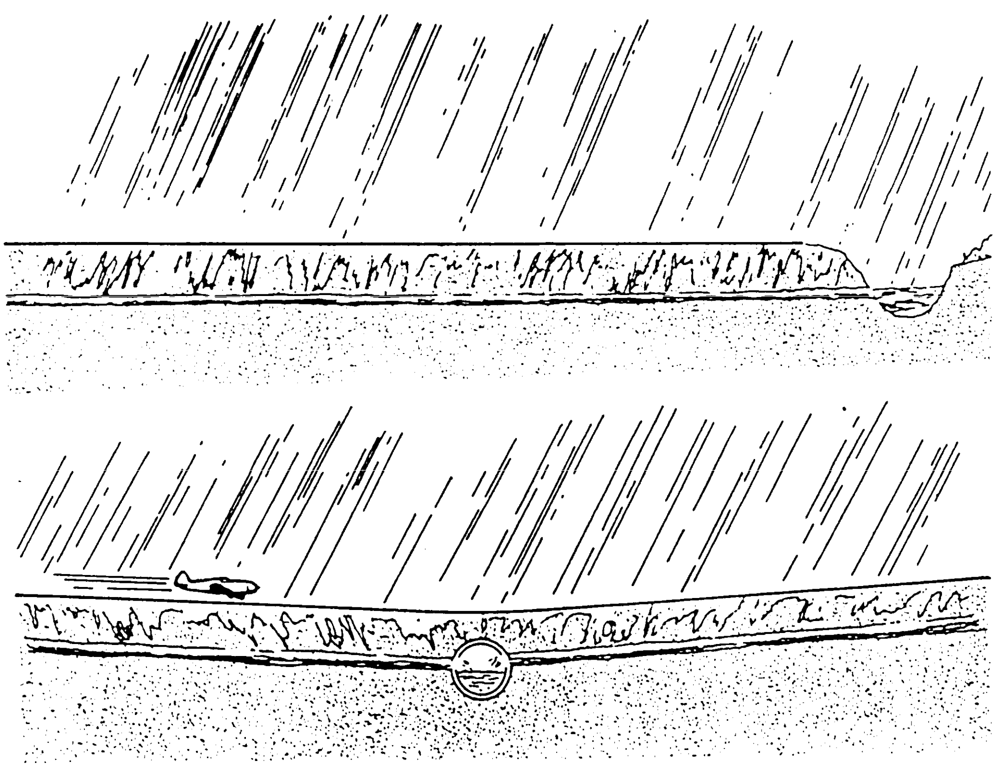


Figure 15-66.—Longitudinal drainage of runways.

GRADING AND EXCAVATING

Grading and excavating are cutting the high spots to grade and filling in the low spots. In cutting down the high spots, enough suitable fill material may be removed to fill in low spots. However, it may be necessary to develop other sources of fill material. If the site is on hard and rocky terrain, loosen and break the soil with a dozer ripper. Before fill material can be placed in low spots, a suitable foundation must be prepared. Material of a low-bearing capacity may have to be dug up before the fill is placed.

Base Course

The base course distributes wheel load stresses from the surface pavement to the subgrade. Since stresses in the base course are more concentrated than in the subgrade, the base course must be stronger.

Placement and Compaction

When placing and spreading base course materials on a prepared subgrade, start at the point nearest the source or at the point farthest from the source. Then place the material progressively away from or toward the source, respectively. The advantage of working from the point nearest the source is that hauling equipment can be routed over the spread material, which helps compact the base course and avoids cutting up the subgrade. An advantage of working from the point farthest from the source is that the hauling equipment further compacts the subgrade, reveals any weak spots in the subgrade, and interferes less with the movement of spreading and compaction equipment.

Base course compaction must produce a uniformly dense layer, conforming in every way to specification requirements. The thickness of the lifts should NOT exceed that which can be compacted to the required density. The thickness of the lifts is determined by the size of the compaction equipment, such as 6 inches for rollers and 3 inches or less when using tampers.

NOTE: Optimum moisture content must be maintained during compaction.